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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.

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STREET ILLUMINATION.

BY JAMES R. CRAVATH.

[Read before the Engineers' Society of Milwaukee, November 10, 1909.]

THE subject of street lighting naturally divides itself into two parts, — first, the selection of the candle-power and location of the lamps; and, second, the selection of the kind of lamps and the supply of energy to them. Since the object of street illumination is to enable us to see along the street at night, the logical way of attacking the street-lighting problem is to first decide on the arrangement and candle-power of lamps which will give us the best results and then decide upon the kind of lamps and the method of their supply. At the risk of being illogical, it will perhaps answer our purposes better to-night to consider the subject in the reverse order, taking up, first, the lamps available, and, second, their location and size.

If we study the broad question of street illumination, we must take up all the various illuminants which are used, including open-flame gas and gasoline, mantle burners using gas and gasoline, kerosene and the various types of electric lamps. I will to-night give most of my attention to electric street lighting, for the reason that this is the kind of lighting with which we are to be most concerned the next few years in our large cities, unless some great and unlooked-for developments of other illuminants take place. For many years gas mantle burners have played a very important and useful part in the economical lighting of the residence streets of our larger cities.

Recent improvements in electric lighting, however, have so reduced its cost that unless there are decided improvements in gas lighting, electricity is destined to be both cheaper and more desirable in other ways. Within the past two years electric lighting has arrived at a point where companies supplying it can underbid those supplying gas for street-lighting purposes, both for lamps of large and small candle-power. An illustration of this is to be found in the fact that electric lighting companies are now supplying tungsten street lamps of the same rated candle-power as gas mantle burners at the same or lower cost per year. This gives the electric light a preference, because of the fact that its candle-power is maintained much nearer to its rating than is possible in the case of gas mantle burners, for reasons which will be explained later.

In the electric street lighting field, changes are going on so rapidly at the present time, because of the improvements which are being made, that the situation is almost confusing at times, even to those of us who are in the midst of this work. We can only surmise what it must be to those not actively identified with it.

Within the past three years we have seen incandescent street lamps come into the field giving from 2½ to 3 times as much light for a given expenditure of electricity as the older incandescent lamps. The overwhelming success of these new lamps with tungsten filaments began to be assured about two years ago. The efficiency of these tungsten lamps is such as to make them more economical as regards consumption of electrical energy than the common enclosed carbon arc lamps which have been the standard for a number of years past for electric street lighting. These tungsten incandescent lamps are made in various sizes for street lighting, from 32 to 250 horizontal candle-power. They are adapted for operation on the ordinary standard series street lighting circuits which are common the country over, so that they can be placed on the same circuits as existing series arc and incandescent lamps, or substituted for such lamps. Because of their ready adaptability to existing circuits, the situation, as regards incandescent lamps alone, is therefore simple.

However, arc lighting has been undergoing equally important improvements in the past three years. These improvements involve not only a change from the existing types of lamps, but also changes in the transformers necessary for supplying them. At the risk of tiring some who are familiar with

electric arc lighting history, I will briefly relate the changes undergone by arc lighting in the nineteen years that I have been actively engaged in the business. In the early nineties, the arc lamp in general commercial use was known as the direct-current open arc. In this lamp the arc is formed between the ends of carbons and the arc burns in the open air without protection, save a large outer globe. These lamps required trimming every seven hours, unless provided with a double set of carbons, in which event the trimming was necessitated every fourteen hours. These lamps, taking about 50 volts at the arc, with a current of 9.5 to 10 amperes, were for some unknown reason in the early days rated as 2 000 c. p. lamps. How this 2 000 c. p. rating happened to be applied has remained a mystery to us of a later generation, and there are various traditions connected with it. One of these traditions is that some one measured the light, and finding that it was about 500 c. p. at a point of maximum intensity, immediately rated it as a 2 000 c. p. lamp, because, when hung at a street intersection, it would give 500 c. p. in four directions; hence 500 times 4 equals 2 000 c. p. At any rate, it has been well established for years that in no way can the old 9.5 ampere open-arc lamp be considered as a 2 000 c. p. lamp, except by virtue of this name having been applied to it for so many years. Likewise, the rating of the 6.6 ampere open-arc lamp as a 1 200 c. p. lamp is based on myth and mystery. In later years, lawsuits have sprung out of this unfortunate nomenclature, — and many an unscrupulous electrician has stirred up a city council by the assertion that the lamps which were supposed to be giving 2 000 c. p. in reality give nowhere near that amount. The candle-power of the 9.6 ampere lamp at the angles most useful for street lighting is between 350 and 500 c. p., the maximum being approximately 1 250 c. p. at an angle of 45 degrees below the horizontal. These old open arcs, many of which are still in use, were fairly efficient as regards the light given for a certain expenditure of electrical energy. From the standpoint of the electric lighting companies or municipalities operating them, their chief drawback was the cost of daily trimming and carbons. From an illuminating standpoint, the chief objection to them was that much more light than was necessary was thrown below an angle of 45 degrees, from the vertical, which resulted in a very brilliant illumination immediately under the lamps. This accentuated the small amount of illumination between lamps. The unsteadiness of the open arc was also objectionable.

The next step in arc-lamp evolution came about 1895, when we began to hear of the enclosed arc lamp. In the latter part of the nineties, this lamp came into extensive use and continued in increasing numbers until a year or two ago. This enclosed arc lamp — which is the one with which we are most familiar to-day — has a small enclosing globe around the arc, which has the effect of making the carbons last longer and rendering the arc more steady. The reduction in trimming cost, however, was partially offset by a reduction in the efficiency of the lamp. Nevertheless, although the total light given out by the enclosed arc was less than that of the open arc, the enclosed arc could be made to give, for street lighting, somewhat greater candle-power for a given expenditure of electricity in directions a little below the horizontal, where the candle-power is most effective for street lighting. While the early arc lamps were only suited for operation from small, inefficient, direct-current machines, the later enclosed arcs could be operated by alternating current from large efficient generators. This, of course, tended to reduce the cost of supply.

In 1903 there began to be rumors of the bringing out of a new commercial street arc lamp known as the "magnetite," or "luminous," arc. In 1906 this magnetite arc had reached a state of commercial perfection which caused a paper regarding a large installation of these arcs at Portland, Ore., to be read before the National Electric Light Association. Since then the luminous magnetite arc has come rapidly into use for street lighting. Its electrodes, instead of being composed of carbon, consist of one electrode of copper and another of various metallic salts, including magnetite, which when burned in the arc give off light and produce an arc of much greater efficiency than the plain carbon arc.

No sooner had the magnetite arc begun to find commercial favor, however, than rumors were afloat of another still more efficient arc, better adapted to use on our standard 60-cycle alternating-current circuits. This arc, which has been publicly announced within the last year, is known as the "titanium carbide" arc. As matters stand at present, this arc is more efficient than the magnetite arc, but requires much higher priced electrodes, which fact under some conditions counteracts the benefits obtained from its efficiency.

Now, the annoying thing about these changes from the standpoint of a company or municipality owning and operating a street lighting plant is that none of these new arc lamps can

be used interchangeably on the transformers and circuits employed for the preceding best type. For instance, the magnetite arc has been commonly constructed and used on 4-ampere constant-current direct-current circuits, whereas the common and most up-to-date practice before this arc came into the field was a 6.6 or 7.5 ampere alternating-current circuit. The use of the magnetite lamp, therefore, usually involves not only the use of new arc lighting transformers at the generator plant, but also expensive mercury vapor rectifying apparatus for changing alternating to direct current at the power station. The new titanium carbide arc is yet in its experimental stage. It appears at present, however, that although it is adapted to operation on an alternating-current circuit, none of the existing alternating-current standard transformers can be used, because these transformers give a larger volume of current than will be necessary for the titanium carbide arc. Nevertheless, it appears probable that the titanium carbide arc will be the most desirable to use in a considerable number of places. We are, therefore, very much in the transitional stage at present, and it is a time for special care to be used in the selection of apparatus and the building or extension of street-lighting systems.

In order to show to you graphically the effect of the advance of the past four years in electric street lamps, I have had figures prepared showing the relative amount of light given by the old and new lamps.

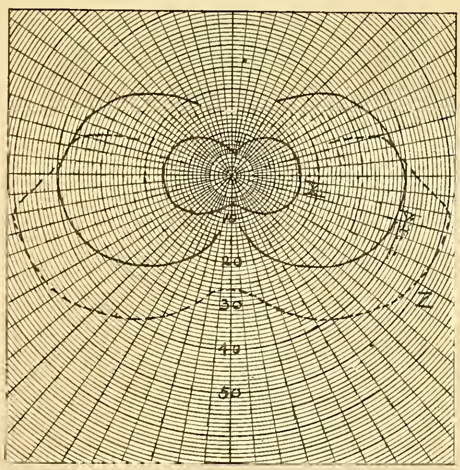


Fig. 1.

Fig. 1 shows the distribution of light about two types of incandescent lamps. These are commonly known as "photometric curves." For the benefit of those not acquainted with such matters, I will explain that the lamp is supposed to be hung in a pendent position at the center, and the candle-power in the various directions is represented by the distance of the curve from the center. Thus, in Fig. 1, Curve X shows the

distribution of light about a common carbon filament incandescent lamp, usually rated as of 16 c. p., taking about 56 watts of electrical energy. Looking at the curve of this lamp, we see that it gives about 16 c. p. in a horizontal direction, and considerably less the nearer we get to the axis of the lamp. Curve Y shows the distribution of light about a 56-watt tungsten filament street lamp, from which it is seen that the horizontal candle-power is 40, as against the old-fashioned carbon filament lamp taking the same energy. Curve Z shows the distribution of light about the same tungsten lamp, equipped as it ordinarily is for street service with a flat fluted white-enameled reflector, twenty inches in diameter. From this it will be seen that the effect of the reflector is to increase the candle-power about 25 per cent. at the angles most useful for street illumination, namely, from 5 to 15 degrees below the horizontal. One may roughly estimate under ordinary street conditions in reasonably clean residence streets that the reduction in effective candle-power due to dirt on lamps and reflectors is in the neighborhood of 25 per cent., thus making the usual rated horizontal candle-power of the lamp the actual effective candle-power for ordinary commercial work. The tungsten lamp has another advantage over its carbon predecessor which is not apparent from the curves. The carbon lamp in use undergoes a slow blackening of the inside of the bulb because of the floating off of carbon particles from the filament. This blackening may be so gradual as to go unnoticed for a long time. The tungsten lamp either goes for a long time without blackening or else blackens so suddenly and decidedly as to be immediately noticeable and cause its removal. In practical work this is a point of much importance. The difference between candle-powers in a laboratory and those obtained on the street is too often lost sight of. For example, the common street gas mantle burner under laboratory conditions may give considerably more than the 60 c. p. at which it is rated. Under actual street conditions, where the adjustment of gas pressure cannot be made from hour to hour, where mantles are likely to become partially broken and defective, the candle-power falls far short of the rated candle-power. Tests made by Dr. Louis Bell, on the candle-power of street lamps in Boston recently, showed that, out of seventeen 60 c. p. gas lamps, fourteen were below 35 c. p. by actual measurement. All but one were below 43 c. p.

Fig. 2 shows the distribution of light about three types of arc lamps, showing the advance that has been made in five

years. Curve A shows the distribution of light about an alternating-current enclosed carbon arc lamp taking 395 watts at 6.6 amperes. This is the common street arc lamp, as we most frequently see it to-day. The candle-power at the most effective angle is somewhat less than 200. As a matter of fact, in practice it probably varies above and below the 200 mark considerably, on account of the traveling of the arc around the ends of the carbon. Curve B shows the distribution of light about a luminous magnetite arc taking 310 watts at 4 amperes. Curve C is that of a magnetite taking about 510 watts at 6.6 amperes. From the curves B and C it is seen that there is a great gain in efficiency between the 4 ampere and 6.6 ampere. The 6.6 ampere magnetite arc is the one which has been recently adopted by the city of Boston for the improvement of its street lighting system. That city at this time selected the most powerful street lamps yet selected by any city in the United States.

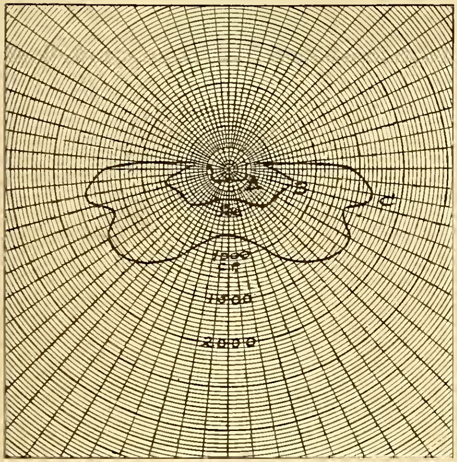


Fig. 2.

Fig. 3 shows the distribution of light about the new titanium carbide arc lamps, the smaller one taking 245

Fig. 3.

watts at 3 amperes and the larger one taking 370 watts at 4.5 amperes. These lamps, which are being tried in three or four cities, have considerably higher efficiency than any arc light yet brought out for ordinary street lighting. The cost of electrodes, however, is high, so that when power is very cheap the magnetite arc, even with all its necessary rectifying apparatus, is the more economical to operate. In external appearance these new arc lamps are very similar to those with which we are familiar. Time does not permit going into the detail of construction of any of these lamps.

The series tungsten incandescent lamp is now ordinarily used with reflector and bracket.

During the past four years a movement has spread over this country for the better lighting of the business streets of both large and small cities. Indeed, the city is now considered somewhat unprogressive which does not have some such special lighting. Various plans have been proposed, some of which are suited only to cities where there are overhead wires in the down-town district. Some of the spans, arches and festoons used in these smaller cities, particularly in Grand Rapids, Mich., give a most pleasing effect at night, but are hardly in keeping with streets where most of the wires have been placed underground.

Among the cities which have extensively adopted special lighting of their down-town streets by means of artistic posts equipped with incandescent lamps are Los Angeles, Cal., where this movement started; Oakland, Cal.; St. Paul, Minn.; Minneapolis, Minn.; Superior, Wis.; St. Joseph, Mo.; Des Moines, Ia.; and Salt Lake City, Utah.

On streets where there are electric railway poles, the merchants and property owners of some cities have decided against the introduction of any additional poles on the street when arranging for special street lighting. In such cases the special lighting is done from specially designed poles which are used both by the electric railway company and for street lighting.

A pleasing combination of railway and street lighting post was recently installed in Salt Lake City. One of the first cities to work out the combination pole idea was Denver, Colo. Its three principal thoroughfares are now provided with posts of this kind, supporting a common old type of arc lamp with opal globes.

In later work done in that city, each post contains one series tungsten incandescent lamp.

Having discussed briefly lamps and other methods of support, we come to the other and most important part of the subject, namely, the illuminating engineering of street lighting. While we may afford lamps of high candle-power at frequent intervals for the special lighting of our business streets, by far the greater part even of our larger cities must for many years be content with lamps rather infrequently spaced. The question of what size or candle-power of lamps to use, and the frequency with which they must be spaced, is therefore of the very first importance in taking up any street-lighting problem. It is not safe to generalize on any of these points. They must be carefully considered for every case taken up. In the outlying or suburban districts of large cities, and in small towns, one can safely say that a tungsten lamp of 80 c. p. at each street intersection gives far better illumination on the street than the customary arrangement of an arc lamp on every other corner. For example, in the case of a couple of small towns for which I have recently planned the street illumination, it was possible by a change of this kind to increase the illumination midway between lamps from 12–1000 to 20–1000 of a foot candle, the arcs in this case being 6.6 ampere. In this case the energy required for the operation of the new tungsten system is only about 50 per cent. of that required for the old arc system.

In larger cities, where there is greater density of population and consequently more money available for street lighting purposes, the question of whether it is best to adopt large arc lamps on each street intersection or smaller incandescent lamps spaced more frequently is not so easy to decide. An engineer can easily figure from the candle-power of the arc and tungsten lamps offered that more illumination can be given at the darkest points midway between lamps by the use of some of the modern efficient arc lamps at each street intersection than by expending a similar amount of money on the smaller incandescent units at more frequent intervals. I may explain here that in all street lighting work it is the point of minimum illumination — that is, the darkest point, half way between lamps — which should always receive first consideration. The illumination of the rest of the space generally takes care of itself. As a general proposition, it is not desirable to have the lamp deliver too much light immediately in the vicinity of the lamp, because it produces too great a contrast and makes the dark spaces appear even darker. We may say that in general we can get a much larger total volume of light from the modern arc lamps than we can

from the modern incandescent lamps for a given expenditure of electrical energy. Furthermore, with our present street-lighting devices, an arc lamp hung at street intersections is useful for lighting in four directions, whereas a lamp hung between street intersections is useful for lighting in only two directions. This fact in itself tends to run up the cost of lighting per mile of street as soon as we introduce either small or large units between street intersections. As I have said before, it is easy to figure mathematically that more light can be delivered midway between lamps by the use of large lamps at street intersections than by small lamps scattered along the street, but here physiology steps in and raises a question. It is obvious that the object of street lighting is to enable us to see along the street. Can we see as well when facing a few large lamps of high candle-power as we could when facing a larger number of lower candle-power lamps? We know from investigations now under way, as well as from practical experience in the past, that bright lamps within our range of vision, when there is but little surrounding light, have the effect of greatly reducing our ability to see clearly. Just what bearing does this have on our street illumination problem as regards the use of large arcs at street intersections versus small units? I must confess I do not know, and I do not think the matter has ever been properly and scientifically investigated. In the light of our present knowledge of lamps, illuminating engineering and physiology, it would not be a relatively expensive matter for any city contemplating a new system of street lighting to conduct some practical experiments under the direction of a competent engineer which should settle some of these points. Such experiments, however, unless carried out with a full knowledge of the real points at issue, might be misleading.

The electric lighting of streets can usually best be accomplished in connection with the other electric light and power business of a city. The power plant and distribution system required for the supply of electric light and power to the modern city is so large that street lighting represents but a small percentage of this business. It is therefore evident as an economic and business proposition that street lighting should be more economically done by companies doing electric light and power business on a large scale than by a company or municipality engaged in street lighting only. The existence of two or three electric-light power distributing systems in a city, each with its separate set of conduits, poles and wires, is not only an economic

absurdity, but a nuisance from the standpoint of the average citizen. The logical way to handle these matters is by a well-regulated monopoly rather than by a competition which cumbers up the streets and in the end benefits nobody. I wish to congratulate you of the state of Wisconsin who have established a sane and sensible way of handling these natural monopolies by means of your public-service or railroad commission. Such commissions, when composed of men of such integrity and fairness as you seem to have secured in Wisconsin, and advised by able and fair-minded experts, offer a most satisfactory solution of many of the difficulties which have arisen between cities and their public-service corporations. Fair regulation can hurt no honestly managed service corporation, nor jeopardize the interests of the public of any city.

Unfortunately, in the past, controversies between cities and the electric-lighting companies giving street-lighting service have arisen. In some cases these controversies have been the result of unreasonable decisions or unfair prices asked by the electric-lighting companies. In other cases they have been the result of dissemination of misinformation regarding the true costs of electric street lighting in the minds of public and city officials. In many cases, if the whole truth be told, there has probably been some unreasonableness and lack of information on both sides of the controversy. It is easy to omit items of street-lighting cost when making statements for publication. Such incomplete reports have been responsible for much trouble in the past. Fortunately, within the past two or three years such matters are being better understood. It is an easy matter for any one to consult the annual reports of the Massachusetts Gas and Electric Light Commission, in which the costs of street lighting, both in municipal and privately owned plants in that state, are given for every city. The commission requires its reports to be made up in a certain way to include all items of expense, and its reports doubtless tell the truth as near as it is possible to obtain it. In the city of Chicago, where municipal electric street lighting has been carried out on a large scale for many years, a report was last year made to the mayor by Mr. B. J. Arnold, the eminent electrical engineer, and by Arthur Young & Co., the well-known accountants, on the actual cost of street lighting in Chicago. From this report it appears that the average cost to the city per lamp per year from 1903 to 1907 was $81.56 per lamp. The cost at the time the report was made is stated to be $50.56 per lamp. The estimated cost in case all

the power were furnished from drainage canal water-power was $42.17. It should be explained that owing to the fact that the Drainage Canal water-power is a by-product of a drainage undertaking paid for largely by the taxpayers of Chicago, the city of Chicago obtains a much lower rate for its purchased water-power than could be obtained from any private water-power company which must pay interest on its hydraulic investment. City electrician Wm. Carroll, of Chicago, in his annual report for the year 1908, gives the cost per arc lamp as $74.12, including all the items included in the report of Messrs. Arnold and Young previously referred to.

In 1907 the Civic League of St. Louis appointed a committee, of which Prof. A. S. Langsdorf, professor of electrical engineering at Washington University, and Prof. J. L. Van Ornum, of that university, were members. After a year of work this committee reported in 1908 at length on municipal lighting in St. Louis. This report contained full discussion of municipal lighting in Chicago and Detroit, the only other large cities in the country to undertake separate municipal street lighting plants. The conclusions of this committee were that a municipal plant in St. Louis could be built which would supply arc lamps at a yearly cost of $69 per lamp. This figure is considerably lower than St. Louis has been paying, but higher than many other cities are paying. The report in general was not favorable to the construction of a city plant. These figures simply show that the cost of electric street lighting is not so marvelously low as the unwary have been sometimes led to think, but that in some cases electric lighting companies have been asking too much.

One thing is certain, however. Cities need much better street illumination than is now common, and whatever is done should be in the erection of higher standards of illumination rather than in a reduction of cost and a maintenance of existing conditions.

DISCUSSION.

Mr. K. A. Albrecht. — Mr. Cravath does not mention the flaming arc lamp as a most economical and suitable illuminant for street lighting. The magnetite arc has unquestionable advantages over the enclosed arc, but neither its efficiency nor its light distribution is as favorable as the flaming arc of modern type. The maximum of intensity of the magnetite lamp is under ten degrees from the horizontal; therefore the maximum of its light flux will illuminate a stratum very much higher

than man's height. It will light up the second floors of the buildings, while the sidewalk and the roadbed do not get any downward light. If the lamps are hung too low, the high intrinsic brilliancy of the arc is disagreeable for the eyes. It is my impression that the magnetite lamp is good for outlying districts on constant-current circuits, and for large spacing.

To get a brilliant down-town illumination, too large a number of lamps per block must not be used. As, in most streets, the poles for the trolley wires are already making the street unsightly, effort should be made to use the trolley poles, making them of artistic design. More than eight lamps should not be placed in a block of four hundred feet.

To my understanding, and according to information of the technical press, the flaming arc in even the older form, with inclined carbon, maximum under 60 degrees, is very much in use abroad, being suspended from really artistically designed poles, thirty-five to forty feet high, with lowering arrangement for convenient and quick trimming. Many of these poles have a basket about twelve feet high, in which flowers are planted in summer, so serving to beautify the streets also during daytime.

Since about two years ago, a new flaming arc lamp with vertical, large core, chemical carbons, made according to patents of the French scientist Blondel, is on the market abroad, and this lamp has the advantage that its maximum of intensity is under 30 degrees from the horizontal, and also that the efficiency of the clear white arc it produces is the same, even slightly better than the yellow of the inclined flame carbon. There is a widespread although unsubstantiated opinion that the cost of the carbons, being imported and paying altogether too high duties, would make this lamp not economical. According to facts and figures I came across, this is not so; but for really brilliant illumination, as it is wanted for the main business streets of the progressive city, this type of lamp, giving white light and using vertical carbons, made according to Blondel's patents, and marketed under the name of Alba, also T. B. flame carbons, is decidedly more economical and unrivaled by others. Berlin, which is acknowledged to be the cleanest and best lighted city of the continent, has its main streets lighted with this Alba or T. B. arc. Budapest, also known as one of the most artistic cities of the old country, has followed suit. These lights can undoubtedly be furnished for constant-current circuits. For large installations, the cost for carbons, including labor for trimming, is around 0.9 cents per hour and lamp.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1910, for publication in a subsequent number of the JOURNAL.]

THE RADERSBURG MINING DISTRICT OF MONTANA AND SOME INTERESTING FEATURES OF ITS GEOLOGY.

By D. C. Bard, Member Montana Society of Engineers.

[Read before the Society, at its twenty-third annual meeting, Butte, Mont., June 8, 1910.]

Location.

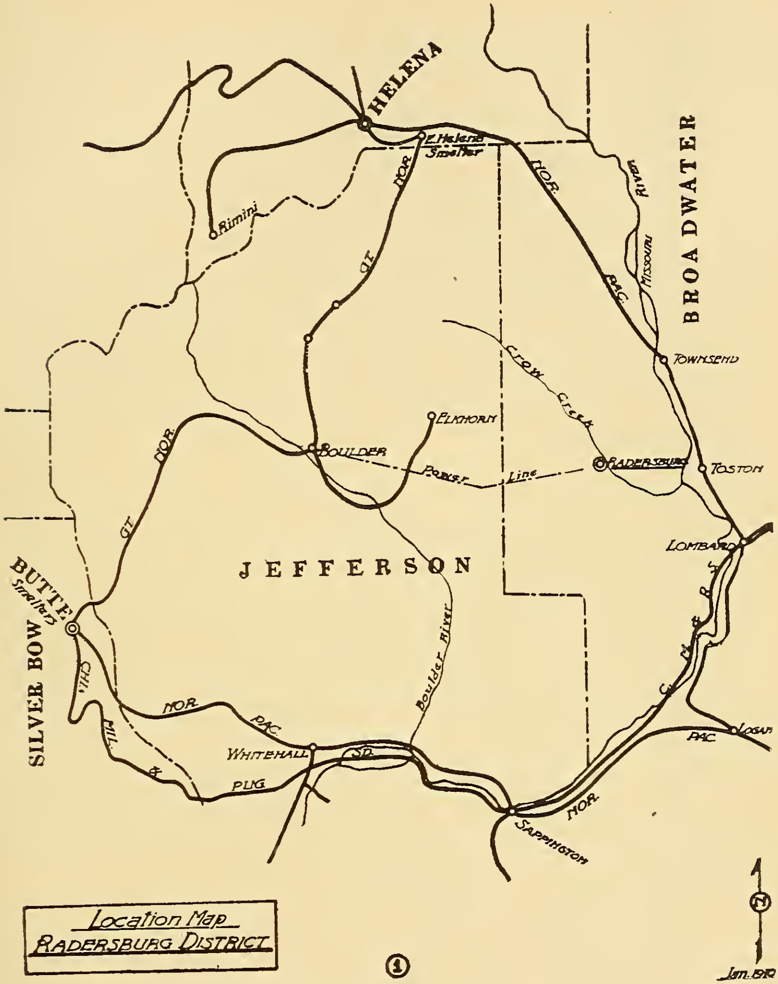
The accompanying map shows the location of the Radersburg District. It is reached by stage or automobile line over eleven miles of level roads from Toston, a station on the Northern Pacific Railway. The camp can also be reached over longer roads from the railway points of Townsend, Three Forks or Boulder. Radersburg has daily mail service and telephone connections. The principal mines are situated in the low, treeless foothills southwest of the town, about 4 500 ft. above sea level.

History and Present Development.

Radersburg is a gold camp which has been the scene of more or less activity for forty years. The first mining was for placer gold, the production of which probably amounted to several hundred thousand dollars. Quartz mining began in the seventies, on the oxidized ores, which were treated by amalgamation after crushing in small stamp mills and arrastras. This mining was intermittent and at no time very productive. Sulphide ores were usually encountered above a depth of 100 ft., and such ores were not milled.

A small blast-furnace was then built at Toston to treat the sulphide ores. This was not a success apparently, for it was soon abandoned. In recent years the sulphide ores of the camp have been in demand by the smelteries at Butte and East Helena, and the resulting low treatment rates have encouraged renewed activity in the district. At present several companies are operating and the camp gives promise of becoming a steady producer.

The Keating Gold Mining Company is the largest operator. It has a vertical shaft 350 ft. deep, and an inclined shaft on the vein about completed to a depth of 600 ft. The property is now being equipped for a production of at least 100 tons a day.



The Black Friday Gold Mining Company is the next largest operator in the camp. It has an inclined shaft 500 ft. deep, which is to be sunk deeper before long. The property is being equipped for a production of 30 to 50 tons a day.

The Ohio-Keating, Rena, Etta and Mammoth properties are in the development stage.

Geology.

The Radersburg ores are found in narrow fissure veins in porphyritic rocks. The veins strike north-south usually, and dip steeply to the west. They are little faulted. The unoxidized

vein-matter consists of auriferous pyrite in a gangue of calcite and quartz. Chalcopyrite, sphalerite, galena, marcasite, pyrrhotite and chalcocite occur rarely.

Fourteen miles west of Radersburg is the Elkhorn District and the eastern edge of the batholith of granite in which occur the Butte ore-deposits. At Elkhorn is found a stratigraphic section from the Algonkian to the Cretaceous, occurring as the west side of a synclinal fold with north-south axis. Passing east towards Radersburg the syncline is succeeded by a well-developed anticline across which a section is exposed down to the Algonkian and up again through the Algonkian, Cambrian, Devonian, Carboniferous, Triassic, Cretaceous and into Tertiary strata (Bozeman lake-beds). On the east side of this anticline, at the horizon of the Cretaceous rocks, is found the Radersburg mineralization.

An extensive zone of igneous rocks breaking through Cretaceous shales, sandstones and limestones occurs here, trending northerly and southerly, and extending for at least twenty miles. These rocks consist of diorites, andesites and some felsites and rhyolite. The mineralization occurs in these igneous rocks or associated with them.

The relations of the igneous rocks are complicated and have not been worked out. Some of the andesites and felsites may be surface flows, though most of them appear to be intrusive.

Secondary enrichment of the oxidized ores is not marked. A ton of oxidized ore may be richer than the underlying sulphide, but this can be accounted for by the fact that it takes about twice the volume of the oxidized ores to make a ton than it does of the sulphides.

There is no indication of decrease of value in the veins to the present depths. In fact, the Black Friday ore-shoots appear to have increased in size and value with depth. This is an unusual condition in gold veins, and deserves comment.

Tertiary lake-beds conceal the underlying rocks over much of the camp. In these lake-beds numerous hot-spring deposits occur. The vents of these hot-spring deposits are calcite veins having usually the same strike and dip as the productive veins. By following the strike of some of the productive veins into the lake-beds the tufas of the hot-spring deposits are found. These facts suggest that the hot-spring deposits may represent a stage of the mineralization of the producing veins, as they both have the same gangue, namely, calcite.

It may be that these Radersburg veins are young geologi-

cally and that the hot-spring deposits represent the final stage of mineralization. Traces of gold are found in the hot-spring deposits. If this assumption is sound, it may account for the increase of gold values with depth in the Black Friday mine. If the veins are so recent that their hot-spring deposits still remain in places, the zone of maximum enrichment from their ascending solutions may be deeper than present development.

The data for the above suggestions are not sufficiently complete to justify the exploration of veins lean at their croppings, but the conditions are worth noting and the developments in the camp will be watched with interest.

Incidentally, a unique question involving the location laws has been raised here. The hot-spring deposits contain sufficient gold to permit a valid lode location. The surface tufas spreading out from the hot-spring vents or veins are an integral part of the lode, though lying flat on the surface of the lake-beds; that is, the tufas are as much a part of the veins in the light of their genesis as are the vertical vents along which the solutions ascended. The question arises whether a location made on the surface tufas without exposing the vertical vents is valid; the tufa has the lake-bed clays for a foot-wall and the sky for a hanging. It is doubtful if the average "jury of our peers" would see it that way.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1910, for publication in a subsequent number of the JOURNAL.]

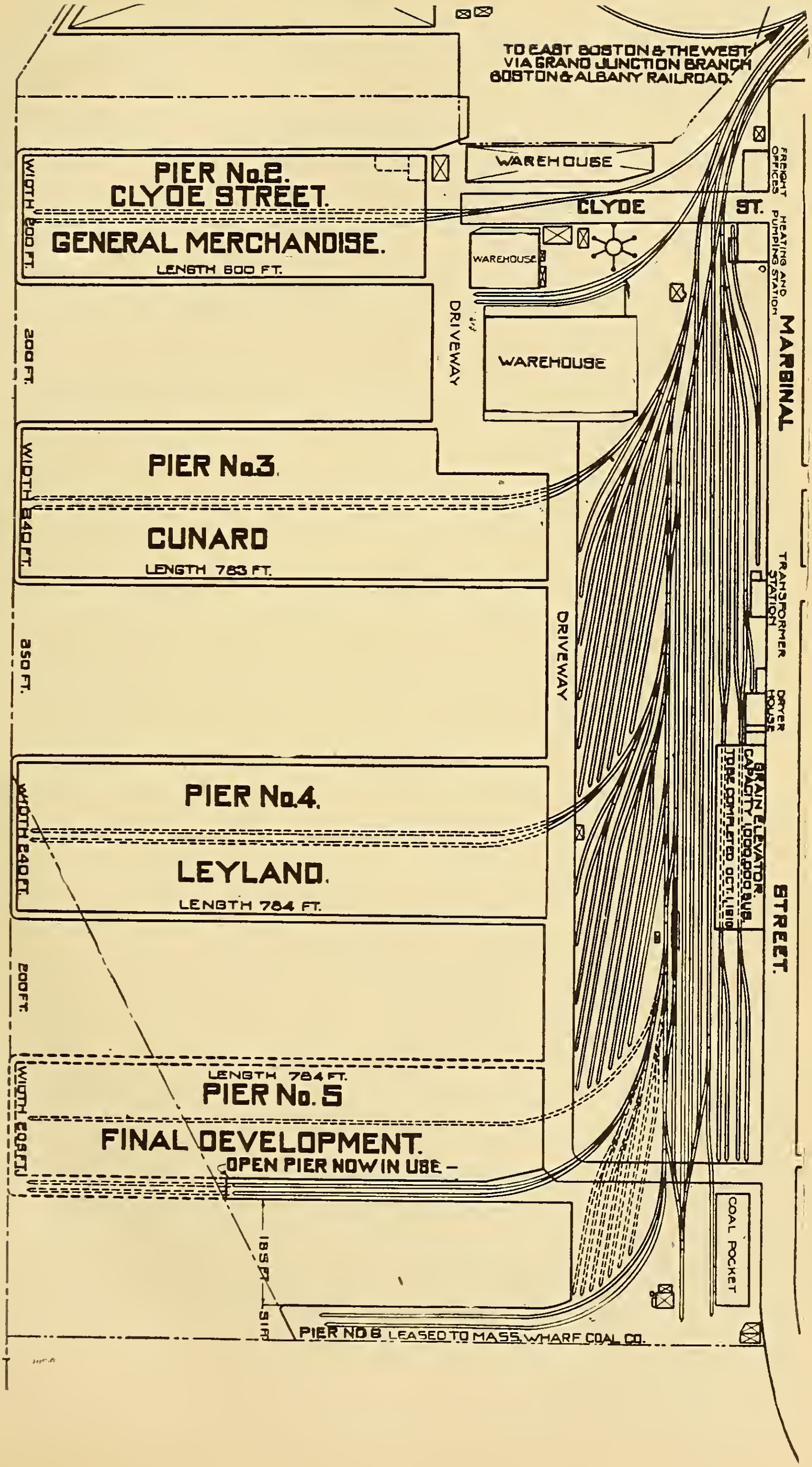
EAST BOSTON DEEP-WATER TERMINAL OF THE BOSTON & ALBANY RAILROAD.

By Luis G. Morphy, Member Boston Society of Civil Engineers.

[Read before the Society, May 18, 1910.]

On the eighth day of July, 1908, shortly after four o'clock in the afternoon, a fire was discovered on the southwest corner of the pier then used for the Cunard Steamship Company's business at the Boston & Albany Terminal at East Boston. With the twenty-five-mile gale from the west at the time, the fire spread with great rapidity, so that, in spite of the fire apparatus brought out by the five-alarm call, the fire had been communicated to the pier then known as No. 2, to the grain elevator and to the pier used by the Leyland Line, within an hour, and these buildings — as well as other annex buildings, such as power house — were doomed to destruction. In fact, it was with difficulty that the fire was checked at the wharf used by the Massachusetts Wharf Coal Company. The only buildings which were saved from the fire were the Clyde Street pier, — which had just been completed in the fall of 1907, — the warehouses, which are of fireproof construction, and the buildings along Marginal Street, the fire causing a loss of about $1 300 000. During the progress of the fire, one man was killed and ten firemen were injured.

Immediately after the fire, studies were made for the reconstruction of the Terminal, enlarging the facilities in every respect; and the work has been prosecuted vigorously, so that at the present time two new piers are in operation, and a portion of the third pier — which will be used as an open pier for general business until such time as it is necessary to construct a shed thereon — is now under construction. The construction of a new all-steel grain elevator, which will have a capacity of 1 000 000 bushels, is also well under way, and it is expected that it will be ready for service in the autumn of this year. In addition, a new freight house has been constructed and been in service about one year; a new engine house and appurtenances, constructed and in operation for about three months; the freight agent's office, which was originally a one-story building, has been moved from the easterly side of Clyde Street to the westerly side of the



TO EAST BOSTON & THE WEST
VIA GRAND JUNCTION BRANCH
BOSTON & ALBANY RAILROAD.
PIER No.2.
CLYDE STREET.
GENERAL MERCHANDISE.
LENGTH 800 FT.
WIDTH 200 FT.
WAREHOUSE
FREIGHT OFFICES
CLYDE
ST.
HEATING AND PUMPING STATION
WAREHOUSE
DRIVEWAY
WAREHOUSE
MARGINAL
200 FT.
PIER No.3.
CUNARD
LENGTH 783 FT.
WIDTH 840 FT.
350 FT.
DRIVEWAY
TRANSFORMER STATION
DRYER HOUSE
GRAIN ELEVATOR.
CAPACITY 1,000,000 BUS.
TO BE COMPLETED OCT. 1, 1910
PIER No.4.
LEYLAND.
LENGTH 784 FT.
WIDTH 840 FT.
STREET.
200 FT.
LENGTH 784 FT.
PIER No. 5
FINAL DEVELOPMENT.
OPEN PIER NOW IN USE -
COAL POCKET
185 FT.
PIER NO 8 LEASED TO MASS. WHARF COAL CO.

same street, raised and had another story built under it; and the general track facilities have been considerably enlarged. In a few weeks it is expected that work will be started on the construction of a heating and pumping plant for general heating and fire protection purposes, as well as a transformer station from which all current for use at this Terminal will be distributed. The cost of the entire improvements is approximately $4 000 000.

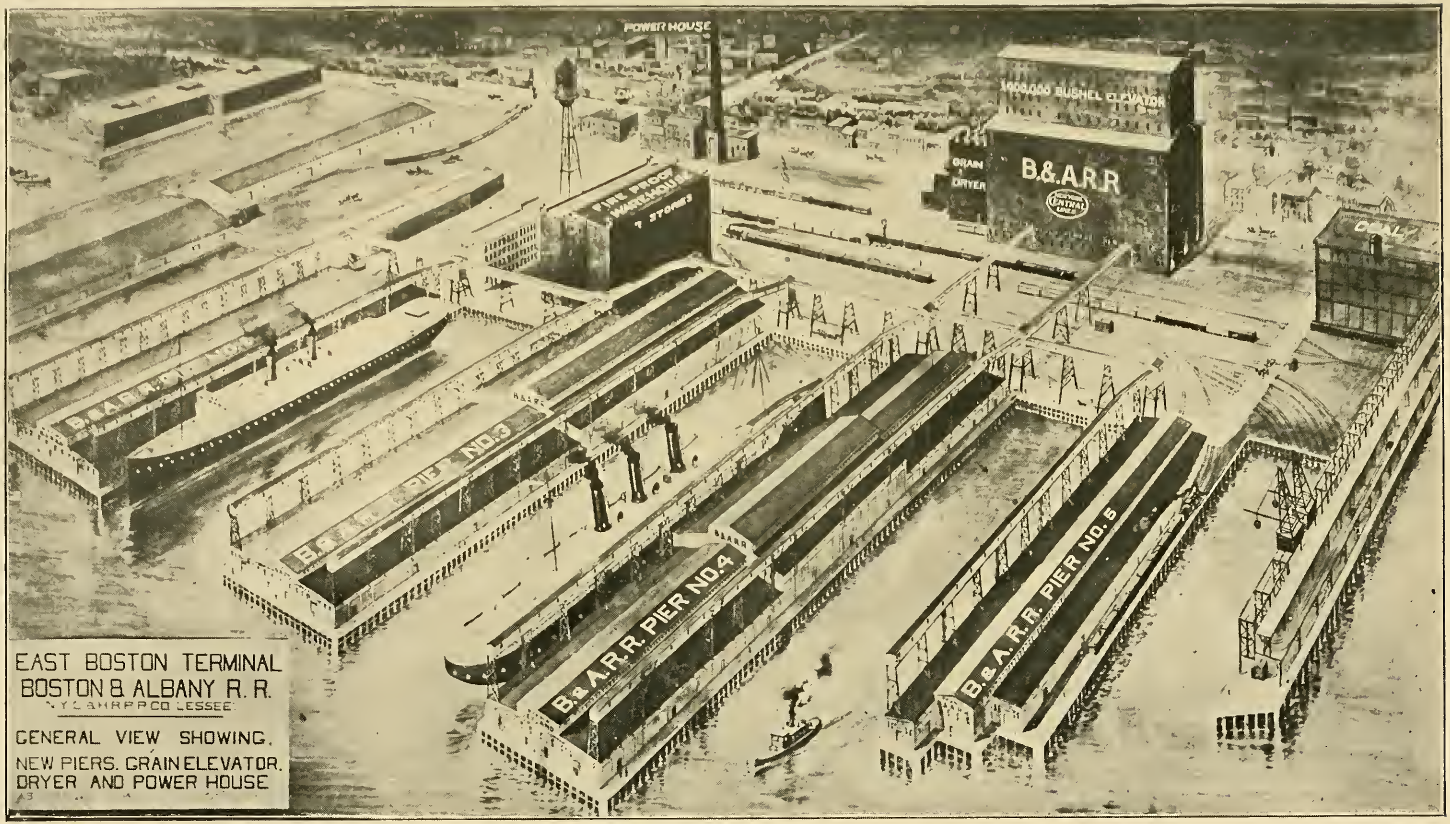
There are certain features of the new layout which are interesting to note. The slips between the piers were widened to 200 and 250 ft., so that it would be possible to accommodate four ships of the *Lusitania* and *Mauretania* type at one time, and still have room between them for lighters to work. The Cunard and Leyland Line piers were made 780 ft. long and 240 ft. wide each, and are the largest piers on the Atlantic seaboard. The general pier is also 780 ft. long, but somewhat narrower than the others in order to leave a slip 155 ft. wide between its easterly side and the pier occupied by the Massachusetts Wharf Coal Company.

Dredging has been done so that the slips will have a depth of from 35 to 40 ft. at low tide, and will thus accord with the $8 000 000 expenditure being made by the United States Government for dredging the harbor so as to permit of the larger ships entering at all times.

The freight house, team yard and engine facilities were entirely removed from the Terminal and rebuilt about one-half mile away from it, on the Grand Junction Branch. Two of the bonded warehouses were also removed to make way for the construction of the new 1 000 000-bushel grain elevator on the southerly side of Marginal Street, and a complete system of grain conveyors installed, so that it is possible to deliver grain to the holds of four ships simultaneously. The Clyde Street pier — which was completed in 1907 — has been equipped with grain conveyors, so that it is possible to load grain on ships docking at that pier.

The trackage at this Terminal was materially increased and rearranged, so that it is possible for switch engines to work on each of the piers without interference with one another.

A general idea of the size of the new piers can possibly be better brought to mind by comparison with other well-known structures, as, for instance, the piers are 240 ft. wide, whereas the Bunker Hill Monument is only 220 ft. in height, so that it would be possible to lay the monument on its side across the width of the pier. In length, the piers are practically three and one-half times as long as the Bunker Hill Monument is high.



EAST BOSTON TERMINAL
BOSTON & ALBANY R. R.
N.Y.C.&H.R.R.R.CO. LESSEE

GENERAL VIEW SHOWING.
NEW PIERS. GRAIN ELEVATOR.
DRYER AND POWER HOUSE

The largest piers in New York City are along the North River, between West Fourteenth and West Eighteenth streets; three of them are 825 ft. long and 125 ft. wide, and each has an area of 103 125 sq. ft. The first floor of the Boston & Albany Pier No. 3, used by the Cunard Steamship Line, has an area of 175 520 sq. ft., and the second floor, 70 400 sq. ft.; while pier No. 4, used by the Leyland Steamship Line, has an area of 187 200 sq. ft., so that it would be possible for the whole of the United States Army to stand on these two piers.

The total area of the Terminal is 1 886 989 sq. ft., or 43.32 acres.

Temporary Grain Transfer.

Immediately after the fire, the erection of a temporary grain transfer building was commenced, and connecting grain galleries, on the final lines as far as possible, were constructed from this temporary building to the Clyde Street pier, so that by the eighteenth day of February the handling of grain was resumed.

Boston & Albany Pier No. 3 (Cunard).

Simultaneously active steps were taken to construct this pier, and contracts were at once awarded for clearing away the débris on the land portion. Contracts were also let for the removal of the old piles, which were burned only to the water level at the time of the fire, and for the dredging, which followed as soon as the piles were removed. The dredging was commenced at the west end of the new Cunard Pier, and the dredged material was disposed of outside of the limits of the harbor, as required by law, there being no available space for depositing it within the Terminal.

As soon as the clearing and dredging operations permitted, foundations for the structure were started. The substructure of this pier is briefly as follows:

A central core of solid earth runs over a portion of the land end, and on this portion permanent foundations for the steel columns and for the support of the two tracks through the center of the pier were constructed. The greater portion of the pier, however, is over water. The foundation is supported practically in its entirety by piles; those on the land portion, where permanent masonry piers are used, being to some extent of spruce, as they are entirely covered with earth. The best of the pulled piles from the old piers were used throughout the structure where

shorter piles could be used. All the piles for the permanent support of the building at the steel columns are oak, and, on account of the difficulty experienced in obtaining long oak piles, a great number are lagged. Where longer piles were needed than it was possible to obtain in oak, and at such points as it will be possible to make renewals in the future without disturbing the stability of the building, southern yellow-pine piles were used. The entire site is what is known as "friction ground," and no hard bottom is obtainable within a reasonable distance of the surface which could be reached by piles of ordinary length, so that the entire building is supported by about 6 200 piles.

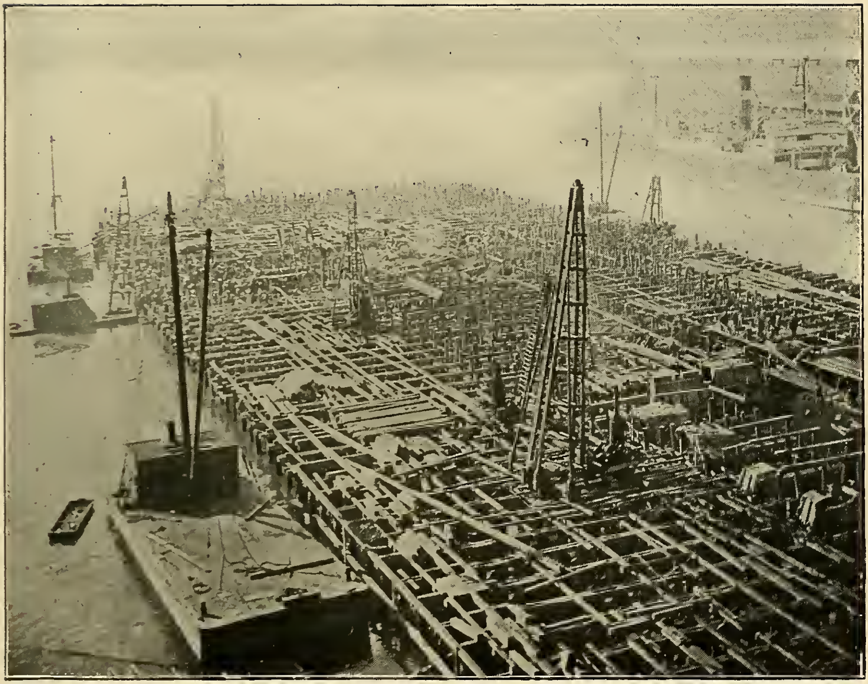
The lumber for capping of piles and framing throughout the substructure where strength and resistance to decay were required, is long-leaf southern yellow pine, wood preservatives being used freely on the outer portion of the structure where it is subject to moisture other than the sea water, and the lumber in the wave stop which surrounds the land core to prevent the action of the waves upon the earth is covered with three coats of Teredo proof paint to retard the action of sea worms which are becoming active in our harbor, but which, fortunately, do not seriously affect oak and some other timber, especially if the bark is on.

On the outer edge of the pier from a distance of 2 ft. below mean low water to mean high water, — about 12 ft. 6 in., — there is a tight wall of 6-in. timber, and from the top of this to the level of the platform of the pier there are concrete slabs, openings only being left in the slabs sufficient for ventilation. All timber in the immediate vicinity of the ventilation openings is protected with fire-resisting material. The object of the continuous curtain of timber and concrete is to prevent burning débris, or burning oil, from floating under the structure.

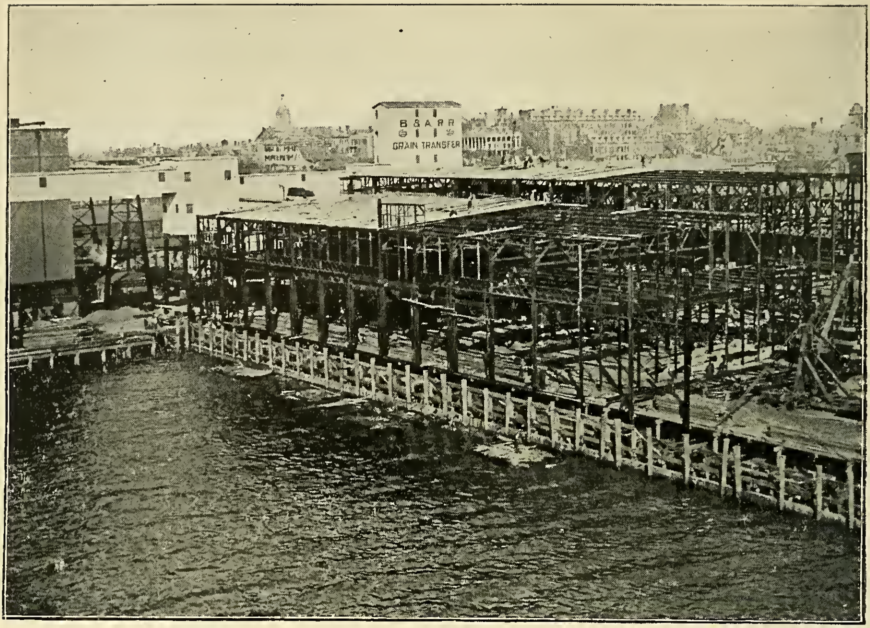
The platform, 10 ft. wide, outside of the pier building, is subject to fire exposure, and is made of solid reinforced concrete slabs 8 in. thick. The floor of the pier inside of the walls of the building is of heavy timbers supporting 3-in. planking. On the planking — to prevent the passage of fire — there are two layers of four-ply plaster board, and on the plaster board a $\frac{7}{8}$-in. matched boarding to protect the plaster board from injury in case of renewals. The wearing surface which is subject to renewals is of 2-in. hard-pine plank.

The plaster board referred to is a material which has been tested repeatedly by the Factory Mutual Insurance laboratories and shown to be one of the best fire-resisting materials known.

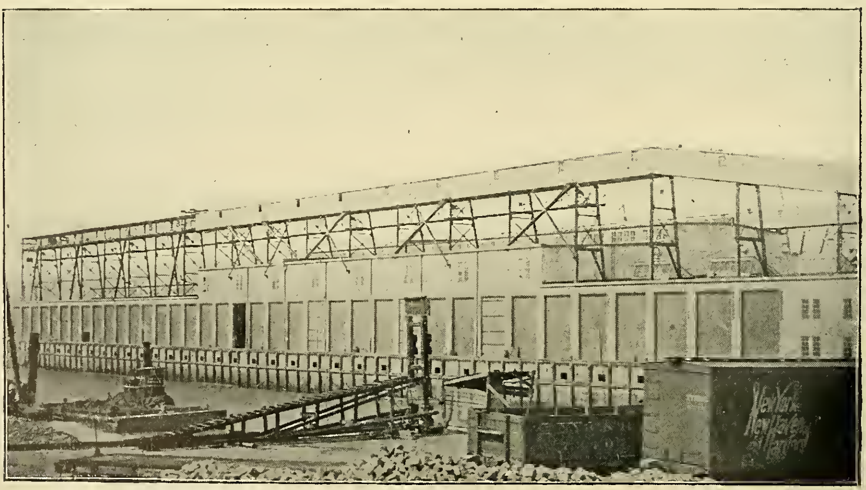
The tracks in the center of the building, previously referred



Cunard Pier Piling.



Cunard Pier Steelwork.



Leyland Pier. Complete except Grain Galleries.

to, are depressed below the general floor level, so that the floor of the cars is approximately on the level of the main floor of the building. A curtain wall of cinder concrete is used as a fire stop between the two tracks. It is therefore seen that, with the exception of protected ventilating openings, the substructure of the pier is enclosed by practically continuous non-inflammable material.

Similar construction to that of the outside curtain wall is used throughout, under both the longitudinal and transverse fire walls; that is, from below low water to a height where timber is always wet, there is a continuous 6-in. sheathing, and above this a solid concrete wall up to the level of the finished floor, from which level the fire walls of the superstructure begin.

The arrangement and number of fire sections was decided upon to prevent the rapid spread of fire, and was the subject of much consideration on the part of the railroad company's engineers in consultation with the underwriters, Chamber of Commerce and the building commissioner of the city of Boston, as were also numerous other details of construction relative to the fire-resisting features of the building.

In connection with the substructure, it was necessary to provide excessively heavy outer corners to receive the impact of the steamers as they are docking, expecially when there are adverse winds and tides. Belaying posts of reinforced concrete are provided at frequent intervals in the outer platform, heavily braced and tied to the structure.

The superstructure is of steel frame construction throughout, consisting of two main spans of about 73 ft., with a central pair of spans about 36 ft. each, the central support being between tracks, thus leaving the main thoroughfare for heavy teaming and general business in the outer 73-ft. span, which is free and clear of all posts and other obstructions. The fire walls are on steel frames throughout. The outer walls, where not made up of doors or windows, are covered with corrugated reinforced asbestos siding.

The doors, which constitute a large area of the sides, are of steel, 14 ft. wide and 19 ft. or more in height. These doors are operated up and down after the manner of rolling curtains, the mechanism for the movement of which is such that one man can easily operate a door. The doors are practically continuous, so that hatches in any position throughout the entire length of a vessel can be accommodated.

Throughout the building, wherever there is any glass sub-

ject to a fire hazard, the glazing is $\frac{1}{4}$ in. thick wire glass, in metal frames having the underwriters' label.

The roof is of 3-in. thick planking protected on the under side with a layer of five-ply plaster board. The outside of the roof is covered with felt and slag roofing, the slag being a lighter and more suitable material for covering than the gravel usually used. All fire walls come through and above the roof and are covered with copper, making tight work with the felt and slag roofing.

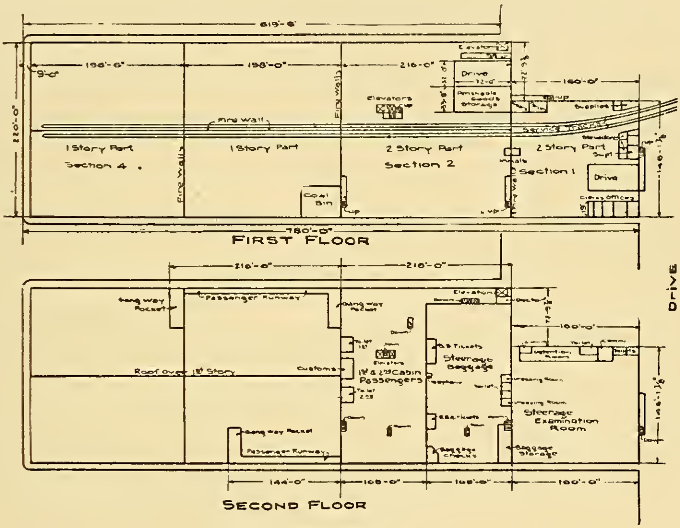
The partitions previously mentioned as having steel frames are covered on both sides with gypsinite studding, on which is applied two layers of four-ply plaster board, making a fire wall about 12 in. thick, with the two sides of the non-inflammable material mentioned, the gypsinite studding being incombustible material, surrounding enough wood only to afford nailing, the whole being practically incombustible.

All openings in the partitions are protected with double tin-covered fire-underwriter doors; that is, a door on each side of the partition, all working automatically, the automatic action being obtained by means of fusible links which melt at the low temperature of an early fire, thus releasing the door which has been only held in place on an incline runway by cords and counterweights, the said counterweights being released upon the melting of the fusible links. The only exception is where it is impracticable to provide the sliding doors, in which case automatic steel rolling doors were installed, the automatic action being here obtained by similar devices to those used in the sliding doors.

On the first floor, with the exception of small areas required for offices in the north end, the entire area is available for cargo. Offices and other conveniences necessary, both on the first floor and on the second floor, are made, so far as practicable, of incombustible material similar to that previously described in other parts of the structure, except that in one or two rooms where special precautions have been taken walls and ceiling are entirely of brick and terra-cotta, and where required for sanitary reasons asphalt or similar material has been used to admit of thorough cleansing. In addition to the offices on the ground floor, a room for perishable freight is provided so that it can be heated if desired, and there are proper conveniences for stevedores' gear. There is also a parcel room on the ground floor for the steamship company's patrons.

The building throughout is provided with a sprinkler system

of approved type. In addition to the sprinkler system, each of the seven large rooms is provided with two hose connections with 75 ft. of hose and two monitor nozzles, the monitor nozzles being such that in the event of a fire the watchman can turn on the water and direct it towards the fire, — the monitor nozzle being left in operation if the watchman is compelled to abandon his post. Fire pails and buckets have also been installed where required.



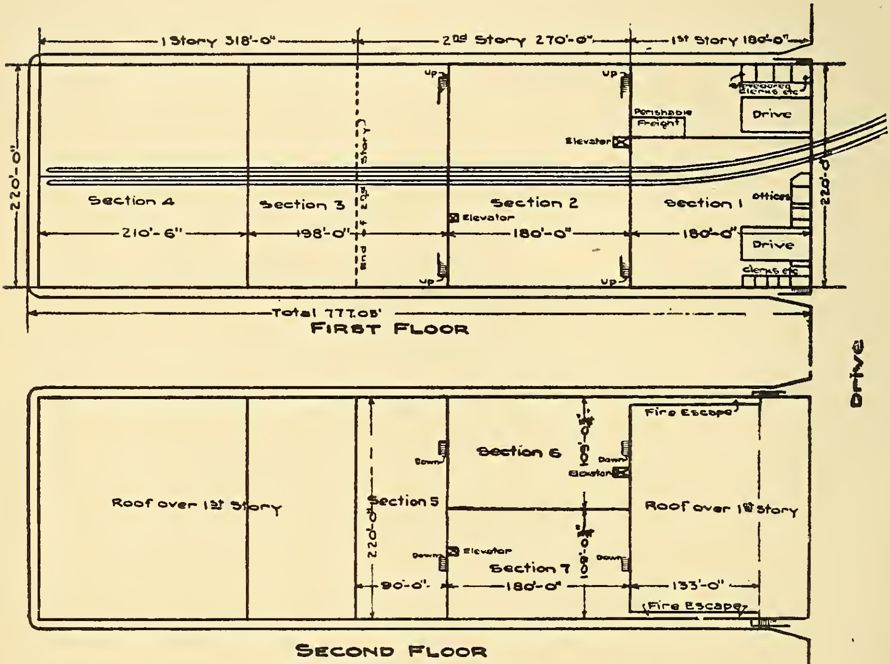
CUNARD PIER

The dry valves of the sprinkler system are electrically controlled, connections being made with the central station on the premises, as well as the general fire-alarm system of the city. Water gongs are also connected with each dry valve, so that the alarm is instantly given on the premises in the event of any one of the sprinkler heads being started by an incipient blaze. The total number of sprinkler heads throughout the building is about thirty-eight hundred.

Water in large quantities is supplied to ships at the dock through a special system of metered service, independent of fire supply pipes. The larger fire-service pipes are installed throughout the yard, connected with the pumps; and a 100 000-gal. tank on steel supports has been erected to provide the so-called double system recommended by the underwriters.

The usual watchman's clock and auxiliary fire-alarm service has been installed.

Drop stages have been provided on each side of the pier, operated by special machinery, to adjust themselves to the receipt of the gangways from both the first and second cabin apartments of the ships, thus making it possible to accommodate very conveniently without unduly steep inclines, the passageways from the ships to the upper floor of the pier where the accommodations for the passengers are located.



LEYLAND PIER

A separate commodious room, 108 ft. by 220 ft., for the special use of first and second cabin passengers and their baggage, has been provided. This space contains convenient and up-to-date toilet accommodations, and rooms for the United States appraisers and other officers. Several exits are provided, in addition to two elevators, either of which can be used for passengers or baggage. These elevators connect with the main floor where patrons can take their carriages and at the same time be in close touch with their baggage as it comes from above. Being on the main floor of the building, the passengers are under cover.

The immigrants are first received in a large space 126 ft. by 160 ft., called the "Examination Room." Just as they enter, they pass before the immigration doctor, who has a convenient

office close by for further examination of any persons whom he finds require it. The room is provided with so-called "lines," consisting of substantial iron railings in connection with settees. At the head of these lines, stationed at desks, are the immigration officers for the detail examination of the immigrant. After passing these officers they are either detained in commodious detention rooms, provided with toilet rooms, until the Board of Examining Officers can make a proper disposition of them, or, if there is no reason for detention, they pass directly to the adjoining room, 108 ft. by 200 ft., where their baggage has been previously deposited. In this room, all the additional business necessary before they can leave the pier is transacted. Money exchange offices, railroad ticket offices and telegraph offices are provided, as well as dressing and toilet rooms. Egress from this room is provided in several directions, for either ordinary or fire uses, and access is provided to the two elevators previously mentioned in the first and second cabin rooms, which are available for use for the steerage business by the time they are needed for that purpose.

Passenger trains are placed in the building directly at the foot of the stairways or elevators, so that immigrants destined for the West are handled without leaving the building. Steerage passengers who are to leave by other means than by rail can take vehicles from the main floor of the building.

So far as the handling of baggage to and from the ships is concerned, stages operated by special machinery are provided, so that baggage may be rapidly received directly from its place at the hatches on trucks stationed on the outstanding stages, and be distributed through the baggage rooms; the first and second cabin coming out first, and later, the steerage baggage, which of course occupies large areas, for the purpose of convenient examination.

This pier was completed and ready for operation on July 7, 1909. The first ship to dock at the pier, the *Saxonia*, arrived July 9, 1909.

Boston & Albany Railroad Pier No. 4 (Leyland).

This pier is substantially of the same construction as the Cunard Pier, No. 3, but slightly larger.

The main differences between the two piers are that on the Leyland Pier tile was used in the fire partitions instead of gypsinite used on the Cunard Pier, and the solid core was larger, necessitating the use of only 5 000 piles.

A portion of the steel superstructure on this pier was put in with a view to adding a second story in the future.

The first ship to dock at this pier was the *Fancturm*, which arrived on January 26, 1910, although the pier was not finally complete at that time.

Boston & Albany Pier No. 5 (General Open Pier).

Up to the present time there has been constructed a portion of this pier of sufficient width to accommodate two tracks at the easterly end, for open business, and it is expected in the near future to construct a driveway alongside and westerly of these tracks. The shed will be constructed in the future as necessity requires.

Grain Elevator.

The new 1 000 000-bushel grain elevator is being constructed on the southerly line of Marginal Street, the dimensions being 269 ft. long by 73 ft. wide, having a total height of 185 ft. 8 in. from the base of rail of track in the yard to ridge of cupola roof. The main structure will contain the steel storage bins 72 ft. in depth, elevated to admit of the passage under them of grain cars. Two tracks run through the building. In the basement below the track level there will be the machinery for car pullers; the boots for elevators, and the watertight boot-leg and receiving tanks. Above the storage and shipping tanks there will be the distributing story, and surmounting this there will be a cupola 44 ft. 4 in. wide by 86 ft. 2 in. high, extending the entire length of the building and divided into four stories, the floors being called the "conveyor floor," "scale floor," "garner floor" and "top floor."

The elevator will be a fireproof steel structure, the main building enclosed with brick walls and the cupola with terra-cotta. The foundations are of concrete, resting on piles. Floors will be of reinforced concrete and the roofs book tile laid on T-irons and made watertight with felt and gravel roofing. The maximum load per pile is 22 tons.

The business of the elevator will be to unload and load cars, and to load ships, including the necessary transfer, drying and cleaning of grain involved in these processes.

The elevator will contain nineteen elevators, of which six will be receiving elevators designed for unloading cars and will be provided with power shovel apparatus; six shipping elevators for loading purposes; five transfer elevators for cleaning and transfer purposes; and two for serving the grain drier.

There will be a grain-drier building of steel fireproof construction near the westerly end of the elevator. It will be about 47 ft. long by 29 ft. wide, and 61 ft. high.

There will be a double conveyor belt system within and next to the southerly wall of the elevator, to receive grain from the shipping bins and distribute to the outside conveyor belt, and a reversible conveyor on the conveyor floor for distributing and transferring grain at that level; also a conveyor belt connection with the drier house. On the ground floor, in the space not needed by tracks, there are to be cleaners, and on an elevated platform there will be the bagging floor, bagging spouts being here provided for loading grain into bags for local delivery. Doors and a protecting canopy will be provided over about two hundred linear feet of the Marginal Street side for the convenience of local patrons. A car loader will also be provided.

A complete system will be installed for collecting dust from the various cleaners, sweepers, elevator boots, garners, etc., the dust being discharged into the dust bin over the dust house at the end of the building. The floor sweep system will provide sixty floor sweeps distributed throughout the building,

It is expected that the elevator will be capable of unloading 300 000 bushels in twenty hours, and shipping 40 000 bushels per hour into the holds of vessels.

All the machinery of the elevator, as well as the belts of the entire conveyor system on the piers, will be operated by electricity. There will be required for elevator and conveyors a total of about 48 motors, varying in power from the small 10-h.p. motor required to operate the passenger elevator in the elevator, to the 100-h.p. motors located in the towers of the gallery system, or for the dust collector fans in the elevator, the greater number being 55 h.p. for operating the grain elevators.

A complete system of fire-service piping, consisting of standpipes with hose, reels, siamese and hose connections, will be installed, with outlets, 28 in number, distributed over the building. The pipes will connect at the west end of the building with the mains from the underwriters' pumps and the 100 000-gallon tank.

From the southerly side of the elevator, — that is, the side towards the docks, — there will extend from two points, conveyor galleries extending to towers at or near the head of the docks, from which place lines, either double or single, will start to reach the sides of the various docks, all galleries being supported on steel trestle bents and composed themselves of steel

trusses with fireproof floors, sides and roofs, the fireproof material being reinforced concrete for the floors, book tile for the roofs, and asbestos sheathing for the sides. The galleries, where over pier buildings, are of steel construction, the steel bents being supported on the steel trusses of the structure.

The grain will be conveyed to the various galleries from the bins in the elevator by means of rubber belts, varying in width from 24 in. to 36 in., running on steel rollers. The power for running the belts is provided by electric motor units stationed at different points throughout the system in the various towers, the electric power being conducted to them through the galleries by an extensive and carefully guarded system of wires. The speed of the belts is about 1 200 ft. per minute, so that 10 000 bushels of grain per hour can be conveyed to any point along the side of the vessels and directed, by means of proper trippers and dock spouts, to and through the hatches of the vessel, the dock spouts being so stationed that any hatch of any vessel can be reached by some one of the numerous spouts.

There will be a total of about 6 000 ft. of grain conveyor galleries, making a total of 7 300 linear ft. of belt conveyors, including those in both double and single galleries.

By means of the double belts the arrangement is such that it is possible to deliver grain to four different vessels at one time, each vessel receiving a different kind or grade of grain. Of course, an elaborate system of signaling from the various points of delivery to the transformer house is necessary, and has been provided both for safety and convenience in all respects, the system being carefully scrutinized by the local board of fire underwriters.

Heating and Pumping Plant, and Transformer Station.

It was originally contemplated to construct a power house at the corner of Marginal and Clyde streets, for the purpose of generating all the electricity needed at the Terminal, to furnish heat and power for the grain elevator, grain conveyors, warehouses, elevators, piers, etc., and for all the electric lighting; but it was subsequently decided to take electricity from the Edison Electric Illuminating Company of Boston for power purposes, and to construct a heating and pumping plant, the dimensions being 47 ft. 2 in. wide by 58 ft. 8 in. long, the portion to be used for boiler room to be 30 ft. high and the rest 23 ft. high. This building will contain two Heine boilers, each having a capacity of 250 h.p. for heating purposes, grain drying, etc.,

and will contain two 1 500-gallon electrically driven turbine fire pumps and one 150-gallon electrically driven turbine service pump. A salt-water intake line will be constructed to be used in case of emergency.

In connection with the fire protection system, a steel tank, having a capacity of 100 000 gallons, was constructed, with hexagon base, having a diameter of 65 ft. at the foundation. The distance from the top of foundation to the balcony is 212 ft. This tank is constructed of open-hearth steel. The live load and wind load used in the design and construction was 30 lb. per square foot. Heating coils are provided to prevent water from freezing.

The transformer and distributing station will be located near the grain elevator, and will be about 20 ft. wide by 50 ft. long. In this building will be installed all the transformers, switchboards, etc.; a complete automatic indicator and a system of communication will be installed, leading to this central point.

New Switching Tracks.

The extensive changes at this Terminal have called for an entire remodeling of the track system. The general features of the track system, as now planned and being executed, are as follows:

Lying parallel to Marginal Street, and between the street and the piers, is an extensive yard of the terminal type, having its entrance and exit at the westerly end. It is divided into five general groups of track, each group separately connected to the main switching leads. On each pier are two tracks also connected to the same switching leads, also two tracks in the grain elevator. The central group is composed of a number of straight tracks which will be used for the reception, making up and departure of long trains of cars. The other four groups will be used for the sorting and storage of cars, for delivery to the elevator and the various piers, one group being assigned to the elevator and one each to Cunard, Leyland and General piers with additional tracks for the Clyde Street and Coal piers. The arrangement is such that switching operations may be carried on in each group without interfering with any other group; in fact, if required, six or even seven locomotives might be at work in the yard at one time without interference.

Some idea of the extent of this yard may be gained when it is considered that there are over five miles of track; that it

will require 325 tons of steel rail and that 80 frogs and switches are required to accommodate the various train movements. The work of loading or unloading may be carried on on 110 cars at one time, all within the lines of the pier sheds, and 430 other cars may be stored on the adjacent tracks awaiting their turn to enter the sheds, making a grand total of 540 cars within the limits of the yard at one time, and still there will be plenty of room for all necessary switching.

Benefits to Boston's Commerce.

What this all means to Boston in the way of commercial development and the extension of her foreign commerce is well understood by her merchants and business men, who, through their new and powerful Chamber of Commerce, have expressed themselves in formal resolutions. The Boston Merchants' Association, now joined with the Chamber of Commerce, passed a vote when the plans for the new Terminal became known, saying:

"The Boston & Albany Railroad is doing all it can to advance the interests of Boston as an important port, and has shown commendable foresight in making such improvements as to anticipate the future needs of the city in its shipping growth."

The building of these new piers and new grain elevator is the one great business and commercial achievement for Boston in 1909. It anticipates 1915, that magic date which has been fixed for the culmination of the movement to make Boston greater both commercially and otherwise, but the Boston & Albany Railroad has gone ahead so that in this year and in 1910 the port will be equipped as it never was before to handle the increased business, and the Boston & Albany Railroad will be able to do its full share of the work of extending and developing the foreign commerce of Boston and making it a bigger port, second only to New York in the volume of its trade. Boston has the advantage over New York in that its larger piers, handling the largest steamships, with tracks and cars alongside the vessels, makes for economy in handling of freight, quickness of dispatch, less chance of breakage on account of the less number of handlings, and advantages over the lighterage necessities at New York.

DISCUSSION.

The President. — I presume Mr. Morphy will be glad to answer any questions, should any one desire to ask any.

Mr. Morphy. — Mr. Russell, our engineer of construction, is here, and I believe he would have some interesting details to talk about if you would give him an opportunity.

The President. — We shall be very glad to hear from Mr. Russell.

Mr. John B. Russell. — I don't know that I can add very much in regard to the piers. In regard to details, there are two features which I might bring to your attention and which are somewhat in the nature of an experiment at the present time. First, the floor of the Leyland Pier. The site of the Leyland Pier covers the location of the old grain elevator, and it was thought best that we retain the old foundation and build thereon the floor for the new pier. And this section is covered with a concrete floor. We therefore have in the Leyland Pier part of our floor covered with timber and part of the floor of concrete. We are able thereby to follow out the result of traffic on the two classes of floors. During the time the plans for the construction of the Leyland Pier were under consideration, the question was brought up of making the floor entirely of concrete, but reports received from the North German Lloyd Pier in New York were such as to cause us to discard that idea entirely, and we are, therefore, experimenting with those two floors, side by side, under the same traffic.

The other feature is entirely a feature of fire protection. The question of how to get water quickly and efficiently and surely to the hose nozzles throughout the buildings during cold weather was one of the difficulties we had to face. The large extent of the piers was such as to make it impossible to keep the mains heated except within restricted sections. Therefore we installed in connection with the piers the pipe mains which are kept heated by a system of steam coils; radiating from these mains are the pipes leading directly to the various hose nozzles and monitors and the supply controlled by hydraulic valves. We have installed in the Cunard Pier an electrical control for these valves. The object we are seeking is to control the water supply from the hose end of the system and without delay. A man, in case of fire, goes naturally to the nearest hydrant, takes down the hose, opens the valve and expects to get water; but as the pipe passes through a cold section of the pier for 400 ft., more or less, no water comes. We have provided for this emer-

gency by placing at every monitor nozzle and hose valve an electric button which stands out with a sign about 8 in. wide and 10 in. high, saying, "To obtain water, press the button." The man breaks the glass, presses the button, the hydraulic valve is operated and water comes. This is the only installation of the kind in the country, and has not been passed by the board of underwriters. It is a new and untried device, and we are testing it. We have installed on the Leyland Pier simply the hydraulic valves and are awaiting the results of the tests before installing the operating device. So far, the electrical control seems to work satisfactorily. We have also, in addition to the electrical control, a mechanical control by which at one point in each section of the pier we can, by pulling directly down on a handle, operate the valve and receive the water. This also will be tried during the summer, and some device will be installed on the Leyland Pier as a result of the tests. If there is any question I can answer in connection with the construction, I shall be pleased to do so.

THE PRESIDENT. — I'd like to ask Mr. Russell how he is going to try these things. Is he going to start a fire in order to test them?

MR. RUSSELL. — At the location of the hydraulic valves have been placed test buttons. A day or two ago I was at the pier and I myself tried them. I could stand beside the valves and press the button or work mechanically any of the valves and see them operate. By closing the main supply valve, there being an auxiliary supply valve for operating, test can be made without letting water into the cold pipes. This makes possible a test, summer or winter. In addition to that, our water is entirely on the metered service, our initial supply being taken from the 100 000-gallon tank and not from the city of Boston direct. In addition to that, we can supervise these valves as part of the supervision system in the watchman's office.

MEMBER. — Is the water let on from the Boston service?

MR. RUSSELL. — The fire protection comes directly from the 100 000-gallon tank, and fire pumps to be installed. The 100 000-gallon tank is to be maintained through an auxiliary pump receiving water from the city service. We are also preparing to install a separate salt-water suction, in case the other supply is not sufficient.

MR. WESTON. — Do you consider the use of power on the piers?

MR. RUSSELL. — The question of power was brought up

in connection with the general pier, only part of which is constructed to date. At the time the plan was up, the traffic conditions would not warrant it. On the Cunard Pier we installed a system of wiring with sufficient estimated capacity to meet future conditions, the idea being that later some form of power would be required. At the Leyland Pier no such wiring has been installed, although a room is provided for electrical work and an electrical switchboard is provided ready for future connections.

A MEMBER. — Mr. Morphy spoke of a load of 30 tons on the piles under the grain elevator. What was the load allowed on the piles under the general structures?

MR. RUSSELL. — I think the maximum load at any one point was 12 or 13 tons. I think there are some cases where a higher load is allowed, and from that down to 6 and 6½ tons. I might say that the piles driven under the grain elevator went much harder than under the piers.

A MEMBER. — What was the size of the steel bars in the posts on the edge of the piers?

MR. RUSSELL. — My impression is that they were one inch.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1910, for publication in a subsequent number of the JOURNAL.]

NOTES ON ROASTING AND SINTERING; WITH PARTICULAR REFERENCE TO THE DWIGHT & LLOYD PROCESS.

By F. M. Smith, Member of the Montana Society of Engineers.

[Read at the twenty-third annual meeting of the Montana Society of Engineers, in Butte, January 8, 1910.]

The subject of roasting is one which interests all metallurgists and is one in which great progress has been made in recent years. In lead blast-furnace smelting of sulphide ores it is customary to subject the ores first to the preliminary process of roasting. The development of the various roasting processes is very interesting, beginning first with the primitive forms of heap roasting, with which the early history of Butte is identified, and followed later by stall roasting. Then came a rapid development of various types of mechanically stirred roasters. Among the earlier forms, which were rectangular in shape, may be mentioned the O'Harra furnace; the Brown-O'Harra; the Allen furnace,—used, I believe, by Mr. Allen in the old Butte and Boston Works at Butte; the Ropp furnace; and the Wethey furnace, as designed by Mr. A. H. Wethey, and now used at the Butte Reduction Works in Butte and at several other plants throughout the country. Likewise may be mentioned the Brown Horseshoe furnace, and the various types of circular hearth shelf furnaces, such as the Herreshoff, the McDougall furnace, and the Klepetko modification of the McDougall furnace, as used at Anaconda. The Godfrey furnace, a single circular rotating hearth furnace with stationary rabbles, is used at most of the American Smelting and Refining Company's plants in connection with the Huntington-Heberlein process. These various types of rectangular and circular hearth furnaces are still in use at various plants throughout the country. Without attempting to describe these various types of mechanically stirred furnaces, it may be stated that they differ in the detail of construction and in the method of operating the rabbles which stir the ore. Each has its advocates among metallurgists, and one may be better adapted for handling certain kinds of ore than the others.

For a long period the Bruckner cylinder was a popular style of roasting furnace, and nearly all of the large plants have had

more or less experience with this furnace. The Bruckner cylinder is now practically obsolete, and the monuments of this process of roasting are still to be seen on the dumps of the various smelteries of the country. At a few places, however, the Bruckner cylinder is still in use, but the indications are that it will soon be entirely replaced by some of the more modern types of furnaces. Among the objections to the Bruckner cylinder may be mentioned the excessive amount of flue dust formed, irregular results and the fineness of the product.

One of the types of roasters, which is the oldest and which has probably been kept in use the longest of any of the types of roasting furnaces, is the old-fashioned hand-rabbled reverberatory furnace. This has long been the standby of the lead smelters, owing to its peculiar adaptability to the roasting of lead ores. Copper smelters have for many years had the advantage of lead smelters in the matter of roasting, for the reason that the various types of mechanical furnaces, and particularly the more recent forms, such as the McDougall furnace, have not been adapted to the roasting of lead ores on account of the tendency of the easily fusible lead compounds to adhere to the plows or rabble blades. As a result, lead smelters have been forced to depend upon the hand-rabbled reverberatory furnace. While this is one of the most reliable types of roasters, it is also very expensive, and a man killer as well. With the invention of the Huntington-Heberlein process, and, later, the Dwight & Lloyd sintering process, lead smelters feel that their time of emancipation from the old hand reverberatory furnace has arrived.

I think I can best describe the preliminary stages of the development of the Dwight & Lloyd sintering process and its fundamental principles by quoting from an article written by Mr. A. S. Dwight, which appeared in the *Engineering and Mining Journal* of March 28, 1908. The first experiments were made at Cananea, Mr. Dwight being at that time the general manager of the Greene Consolidated Copper Company, and Mr. R. L. Lloyd, the metallurgist. Mr. Lloyd, by the way, is a member of this Society, and was formerly connected with the Boston and Montana Smelter at Great Falls.

Extracts from Mr. Dwight's Article in the *Engineering and Mining Journal* of March 8, 1908.

" The effectiveness of an air blast in hastening roasting has long been recognized, but the very rapidity of the reaction defeated its own ends, for the sulphides quickly melted together,

and impeded further oxidation. Huntington and Heberlein found that they could prevent this premature matting of the sulphides by mixing lime with the charge, just as had been done for generations in the old Flintshire lead practice. The particles of lime served to keep the particles of galena separated during the oxidizing period, thereby favoring individual roasting of the sulphide particles, as distinguished from mass roasting. Until this precaution was observed, blast roasting never had a chance to show what it could do, and, the first time the partially roasted charge so prepared was transferred to the converter and treated with an air blast, the remarkable possibilities of roasting in that way must have become apparent. But in order to account for the astonishing results, it seemed for a time necessary to assume the existence of compounds and reactions of lime heretofore unsuspected or considered as impossible.

"*Principles of Lime Roasting.*

"These assumptions were widely discussed and largely accepted. Careful research, however, proved them to be fallacious. Now, it is quite satisfactorily established that the function of the lime is mechanical rather than chemical, and a brief statement of the principles involved would be as follows: Make up a charge in which sulphides are mixed with other ingredients, so chosen that during the first or roasting period they shall remain more or less inert, acting as isolators to prevent mass action among the burning sulphide particles, but which subsequently, during the second or agglomerating period, shall be capable of uniting with the metallic oxides produced by the roasting, and with the other ingredients of the charge, to form silicates or other compounds which will become sufficiently viscous at the temperatures developed by the reactions to cement the mass together more or less into what we call a sinter.

"The Huntington-Heberlein procedure still uses the reverberatory furnace for the preliminary roasting. The Carmichael-Bradford and Savelsberg procedures generally perform the entire operation in the one converter, and both plans are justified by special conditions of the problem.

"The results achieved by Huntington and Heberlein in building up, by a combination of old and almost discarded metallurgical methods, a practically new process, and making it a brilliant commercial and technical success, deserve the highest commendation and praise. It unquestionably marks one of the real advances in the metallurgy of lead and copper in this generation, and has been largely adopted by lead smelters in all parts of the world.

"*Defects of the Blast-Pot.*

"It must be conceded, however, that even the best form of blast-pot or 'converter' which has heretofore been used for these pot-roasting processes is open to many serious disadvantages, chiefly mechanical, of which the following list will suffice:

"(1) The process is necessarily intermittent, requiring much handling of material, and constant attention in filling the pots, stopping blow-holes, etc.

"(2) On account of the agitating effect of the blast as it issues from the top of the pot, there is a considerable quantity of the charge, particularly near the top, which though partially roasted, does not have a chance to sinter. In order to reduce the percentage of these unsintered fines, the capacity of the converters is made very large, usually about ten tons to the charge. Under average conditions the quantity of fines will amount to from 10 to 30 per cent.

"(3) On account of the mass action in such a large converter, the central part of the sinter cake is apt to fuse together into a solid mass of slag, and thus lose the peculiar, cellular, cokelike structure which is such an important desideratum of the product. It also involves much extra labor in breaking up the mass after it has been discharged from the converter.

"(4) It has been shown by H. O. Hofman (see paper on 'Lime Roasting a Galena Concentrate,' Trans. A. I. M. E., Vol. XXXVIII) that the sintering action in an ordinary converter, blown from below, starts at the place of ignition at the bottom and moves slowly to the top; and the time during which a given particle is exposed to the maximum heat of sintering (1 000 to 1 200 degrees cent.) is not more than a minute or two, the temperature curves for a given layer in the converter showing a very sudden rise to, and a very sudden fall from, the critical temperature-time of sintering. When this slowly rising plane of fire reaches the top surface of the charge in the pot, the operation is completed. It must be very evident, therefore, that in a converter of many tons' capacity most of the space is occupied by particles which are either waiting to be sintered or, having been sintered, are waiting to have the rest of the charge finished. Hence the greatest part of the capacity of the converter is used for storing and not for actually treating its contents, and we are therefore forced to the conclusion that, considered strictly as a metallurgical furnace, the capacity-efficiency of the Huntington and Heberlein converter is very low.

"*Ideal Conditions.*

"If this reasoning is correct, it follows that ideal results as to character of product and economy of operation would be obtained: (*a*) If the treatment could be made continuous; (*b*) if the material could be presented and maintained in a quiescent condition; (*c*) if a thin layer, charge or succession of charges could be employed.

"After some very extensive experiments in this direction by R. L. Lloyd and myself, we found that one very important matter was to follow such a course that, from start to finish, the particles throughout the entire mass were prevented from agitation, or disturbance, and particularly those particles in that part of the mass in the region where the gases made their exit.

In other words, we discovered that complete quiescence was one of the incidents of superior sintering, which apparently requires that at the instant of maximum temperature all the particles of the mass in that locality must remain in practically the same relative position and in close contact, each with its neighbors. There are many ways of accomplishing this effect, and with a great variety of apparatus, employing up-draft, down-draft or side-draft."

Last August we installed at the East Helena plant one of the latest types of the Dwight & Lloyd machines. This machine, called Type E, or straight-line machine, is 28 ft. long over all, with an effective area of 30 in. wide by 150 in. long, or 31.25 sq. ft. This machine has a system of grates 30 in. wide, carried on a train of independent cast-iron pallets, actuated by means of a pair of sprocket wheels driven by a 10 h.p. motor. As a matter of fact, the actual power used to run the machine is only about 1 or 2 h.p., and this same 10 h.p. motor also operates the pug-mill mixer and the platform elevator for elevating the ore to the storage hopper above the machine. Briefly, the process reverses the action of the Huntington-Heberlein pot-roasting process. Instead of blowing air upward through the charge, as is done in the Huntington-Heberlein pots, the air is sucked downward through a thin layer of ore resting on a system of traveling grates, which move over an airtight windbox connected with an exhaust fan. This fan produces a suction, drawing the air down through the charge on the grates, and discharging the gases into a flue. Just at the point where the grates begin to travel over the wind box, the charge is ignited by means of a gasolene jet under about 80 lb. pressure. (In some places a coal fire is used for ignition.) The ore has to be properly prepared for the machine in order to get good results. A thorough mixture of the various ingredients of the charge must be made, and the charge should be crushed to about $\frac{1}{4}$ in. and finer, if not already so fine. A certain amount of moisture is also necessary. Having the preliminary conditions properly adjusted, the charge ignites readily, sinters evenly and produces a most excellent spongy product, running between 3 per cent. and 4 per cent. sulphur. The tonnage put through our machine is in the neighborhood of 40 tons per day, or about four times the roasting capacity of one of our reverberatory roasting furnaces which has a hearth area 14 ft. by 60 ft., or 840 sq. ft.

We have found that even with this one small machine, the operating cost compares favorably with that of the Huntington-

Heberlein process, operating on a much larger daily tonnage; and with an installation comprising several larger machines it is expected that the costs will be greatly reduced. I will say that we are now planning to install at East Helena two additional machines, each having a capacity of about 100 tons per day. Personally I do not expect that the Dwight & Lloyd sintering machine will necessarily do away with the Huntington-Heberlein process, but it certainly ought to entirely supersede hand reverberatory roasting. I believe, however, that the Dwight & Lloyd machine is capable of great expansion, and will be a very important factor in the development of the process of sintering.

In treating matte and heavy sulphide ores in the Huntington-Heberlein process, it is necessary to preroast the ore to about 10 per cent. sulphur before blowing in the pots. This is done in the Godfrey furnace, which has a revolving hearth with stationary arms. The Huntington-Heberlein process has not been particularly well adapted for extremely fine ores, fine concentrates or flue dust. Our experience, however, has shown that the Dwight & Lloyd machine is much more flexible in the character of the charge which can be treated, although it is distinctly intended for fine material. For this reason coarse ores should be first reduced to a degree of fineness between $\frac{1}{8}$ in. and $\frac{1}{4}$ in. in size to obtain the best results. Various mixtures which have been treated on the Dwight & Lloyd machine at East Helena have contained as high as 15 per cent. to 20 per cent. flue dust, together with a similar percentage of matte. In roasting matte it has been found necessary to crush fine in order to secure successful results. Experiments have proven that by crushing to $\frac{1}{8}$ in. and finer, as much as 40 per cent. to 60 per cent. matte can be put into the mixtures. Two characteristic mixtures which we sintered on the Dwight machine at East Helena were made up about as follows: 68 per cent. lead concentrates and slimes, 12 per cent. raw matte crushed fine, and the remaining 20 per cent. made up of miscellaneous sulphide ores and fine concentrates. The average analyses of these two mixtures were as follows:

	SiO_2.	Fe.	Mn.	S.	Zn.	Pb.	Cu.
No. 1	15.4	17.2	0.9	14.4	5.2	29.6	0.8
No. 2	11.5	16.9	1.0	13.0	2.7	30.0	1.0

These mixtures were sintered at the rate of 40 tons per twenty-four hours, and made an excellent sintered product having the following analyses:

	SiO_2.	Fe.	Mn.	S.	Zn.	Pb.	Cu.
No. 1	16.0	18.2	1.0	3.8	4.6	35.5	0.5
No. 2	13.6	18.9	1.0	4.0	6.3	35.0	0.8

The various constituents of the charge are bedded in bins and the charge is elevated in a platform elevator and dumped into the storage hopper, which discharges over a short belt conveyor into a screw conveyor pug mill, which in turn discharges into the feed hopper of the machine. The ore charge must be properly sized and thoroughly mixed in the pug mill with the admixture of a little moisture, which is approximately 4 per cent. or 5 per cent. This moisture is absolutely essential for the best results. After the ore is fed on the grates, a series of brushes, reaching clear across the full width of the grates, smooths the ore down; and this is followed by a wooden roller which packs the ore to the right degree on the grates. The ore then passes under the gasolene igniter, the gasolene vapor being under 80 lb. pressure. This ignites the charge thoroughly clear across the full width of the grates just as the ore begins to move over the suction box. After the sintering action is complete down to the grates, the product is automatically discharged off the grates into dump cars. The product is well sintered, with almost no fines, and the sulphur contents vary between 3 per cent. and 4 per cent.

Before closing, I would like to call attention to the results which, I am informed, have been obtained by the use of the Dwight & Lloyd sintering machine on copper blast-furnace flue dust. At the Tennessee Copper Company's works at Copper Hill, Tenn., a very large pile of copper blast-furnace flue dust has been accumulating for years. Recently one of the latest types of the Dwight machine was installed at Copper Hill for the purpose of handling this flue dust. The results, I understand, were highly satisfactory and were accomplished without the admixture of any other material. The Tennessee Copper Company's flue dust has about the following analysis:

Cu.	Fe.	SiO_2.	S.
1.9 per cent.	28.8 per cent.	27.0 per cent.	10.0 per cent.

The average size was between 30 and 50 mesh. One of the old piles contains a great deal of flue dust which was cemented together, so that it came out in lumps. Attempts to sinter this on the machine proved very troublesome at first, as it was in places impervious to the blast, causing raw spots to be produced in the sinter, also resulting in a large percentage of fines. It was then decided to break these lumps up in the pug mill, running

at from 400 to 500 rev. per. min., whereupon the results were entirely satisfactory.

This machine is now running steadily at Copper Hill and handling over 60 tons dry weight of flue dust per twenty-four hours.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1910, for publication in a subsequent number of the JOURNAL.]

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THE CONTAMINATION OF CITY AIR.

BY DR. GEORGE A. SOPER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Sanitary Section of the Society, March 2, 1910.]

IT is always a great pleasure to me to come back to Boston. I began my career here about fifteen years ago, and was very proud to join this Society as one of my first technical affiliations. Since then I have come more often, I think, to read papers before some of your medical societies than I have to appear before you in reading papers or discussing them. It happens, I might say in explanation of that fact, that my experience has carried me unusually far in lines which are customarily considered medical. But, as I think, medical men usually know very little about the cause of typhoid fever, and are not as interested as they should be in preventing it; so that I consider it a distinctly engineering work that I have been doing and telling them about.

I thought, earlier this evening, that I should have to begin with an apology to you, because I learn it is not customary to invite the same person to come repeatedly before you. It seems to have been forgotten that I was here two or three years ago. Apparently I didn't create a very deep impression. But in any event, the fault of my coming here is my own, because I didn't want to lose this opportunity of telling you some of the things I have been finding out about air. They are things we all ought to know. They are things that most of us, I think, do suppose we know, but they are not as clearly framed in our minds as they might be. I have jotted down, for the sake of economizing time,

some remarks on "The Contamination of Air," which was the subject I was requested to talk about, and after running over these notes, I will invite you to see a few photographs.

The Contamination of Air.

About forty years ago the cause of sanitation was materially aided by the appearance of a book of moderate size in which the author undertook to cover the whole subject of hygiene. The book was divided into several chapters, each of which dealt with a separate topic of fundamental importance. One of these chapters was called "The Air We Breathe"; another, "The Food We Eat": and a third, "The Water We Drink."

In the period which has elapsed since the appearance of this book all branches of science have progressed prodigiously, and as sanitary science, which is the application of all knowledge to the conservation of life and health, has advanced correspondingly, there is to-day no volume or set of volumes which can pretend to give an adequate treatment of the whole subject.

The changes of opinion with respect to the cause and prevention of disease which the new knowledge, especially of bacteriology, physiology and chemistry, has produced, have been revolutionary. The entire basis upon which the sanitation of cities should rest was changed when it was discovered that infectious diseases could not originate in filth and foul odors, as had always been supposed, but were ascribable in every instance to some pre-existing case of disease, just as the existence of a grain of wheat is ascribable to some other grain of wheat which has gone before and served as seed.

It is interesting to note that in the progress of sanitary science nothing has occurred to shake the opinion that the air we breathe is by all means the most important single matter to which sanitarians can give attention. As a recent anti-tuberculosis campaign poster put it: "Man can do without food for three weeks, and without water for three days, but he cannot do without air for more than three minutes."

There is a singular difference between our requirements for air and our need of other life-sustaining elements. We are generally much less fastidious about the composition of our air than about the composition of our food and drink, and yet health and efficiency are profoundly affected by the quality of the 400 cu. ft. or so of air which we daily take into our lungs. Send your pale city man to the country and see the visible improvement in energy, spirit and strength which he at once experi-

ences. The evil effects of bad air are not so immediately apparent. They are generally hidden for so long that the victim comes to believe he is immune, or that the danger has been exaggerated. But eventually the price is paid.

Air, like water, is, in natural condition, pure. It is to man's use of it that the most harmful attributes which it sometimes possesses are due. So far as the essential gases are concerned, the atmosphere of the prairies is as pure as that of the sea, and the air of the marshes is as wholesome as that of the mountains. In the open there is as much oxygen in one place as in another. Much of the difference in chemical composition which seems to exist is due to differences of temperature and humidity and the effect of various conditions acting agreeably or otherwise through the senses of sight and smell. The point most worth bearing in mind in considering this question is that under the natural conditions which exist in the free, open atmosphere of the country there is always enough oxygen for life and health, and rarely any other gases which can do either good or harm. It is the air of cities, and especially the air of inclosed spaces, that is likely to be contaminated.

It is doubtful whether ozone actually exists in the atmosphere. Sir William Ramsay has expressed the opinion that it does not exist. Yet the scientists of the Montsouris Observatory of Paris make determinations of what they consider to be ozone regularly, and we have in New York City, in Central Park, an observatory where Dr. Draper has been making what he considers to be ozone determinations for a long time. We have recently had ozone recommended as an air purifier. A few years ago, in the Paris subway, I saw an ozone machine, a machine for throwing ozone into the atmosphere in the hope of improving the conditions of the air. Ozone is a curious form of oxygen which produces an opposite effect — at least, when fairly concentrated — to what one would expect of a healthful agent. It produces the symptoms of influenza, as I can testify, having experimented considerably with it in the laboratory in experiments to sterilize water. Professor Leeds, of Stevens Institute, had to give up experimenting with ozone entirely because of its unpleasant effects.

The air impurities which are worthy of notice do not belong to any one class or group of substances, as do the water impurities which affect health. Aërial contamination may be chemical, physical or microbic. By chemical impurities is meant chiefly the gaseous products of industrial works, compounds

produced in the combustion of coal and illuminating gas. It is unnecessary to make extended mention of the effects of these gases, although the fact should be noted that carbon monoxide, a prominent ingredient of the gas which is produced when coal and other carbonaceous matters are burned with an insufficient supply of air, is a powerful poison, which not infrequently causes death in mines and elsewhere. Methane is the greatest danger of mines. It is produced when organic matter is decomposed in the absence of air and presence of water. Sewage septic tanks give it off, for example. Methane, like carbon dioxide, destroys life by diluting the oxygen present. There must be a large proportion of it to affect one seriously. It is explosive when mixed with about ten times its volume of air.

There is no gas known to science as sewer gas, the ghost which formerly went by that name and was supposed to creep with deadly effect into dwelling houses through plumbing fixtures having been laid years ago. Sulphureted hydrogen, methane and carbon dioxide are often present in the air of sewers, as is the much more dangerous illuminating gas and gasolene vapor. These two have from time to time caused startling explosions in the sewerage systems of New York and other cities. The Metropolitan Sewerage Commission of New York, to which I have the honor to belong, has made a systematic inspection of the sewers of Manhattan Island in coöperation with the Department of Public Works, and one of the specifications which we made in that coöperation was that our men were not to be sent down in what is called the gasolene district.

Turning to gaseous impurities due to the presence of human beings, it is reassuring to know that air which has passed through the lungs possesses practically no poisonous properties of chemical composition in spite of the teachings to the opposite effect which are a favorite theme of text-books. The unpleasant odors are objectionable chiefly because they are unpleasant. Perhaps that statement should be qualified to this effect, that although every effort has been made by scientists for years to detect the presence of poisonous products of respiration, those efforts have been without success. Some years ago a number of men who became somewhat famous as a result of their researches came to the opposite opinion. They believed that gaseous poisons were produced by breathing air. But we know now that their technic was imperfect and that the animals that were experimented upon were poisoned otherwise than by products of respiration.

The air of an overcrowded and badly ventilated room is slightly lacking in oxygen, but the deficiency is generally not great and under ordinary circumstances is readily compensated for by an imperceptible acceleration in the rate of breathing. Accelerations of far greater extent than any which are likely to be produced by a deficiency of oxygen due to bad ventilation take place upon the slightest exertion in any atmosphere.

Air which has passed through the lungs is loaded with vapor and with carbon dioxide, but in view of the harmless nature of the latter gas its presence need not, under ordinary circumstances, be considered of great importance. The danger of chemical poisoning through breathing an atmosphere charged to the extent of one part of carbon dioxide in a thousand parts of air, which is the limit often set by law for factories and workshops, seems trivial when we consider the quantities of undiluted carbon dioxide which are taken into the system with tobacco smoke, beer, mineral waters and sparkling beverages generally. The sanitary significance of carbon dioxide lies in the index which it affords of the presence of other and more dangerous impurities of human origin. Tests of air for carbon dioxide are like tests of water for chlorine, — they furnish a clew to the presence or absence of harmful microbes.

The free atmosphere, that is, the air out of doors, possesses a sensibly beneficial quality which has baffled the keenest investigators to explain and it cannot be produced artificially. Some years ago a number of scientists were appointed to examine the air of the meeting rooms of the Houses of Parliament. They were given liberty to choose the most refined methods of analysis, and were instructed to determine why it was that the ventilation of those rooms was not satisfactory. The scientists reported that the cause of the unsatisfactory condition of the air could not be determined, but that there was a perceptible lack of freshness about the atmosphere That freshness, the quality which we all have noticed in going out of doors, can never be obtained in a completely inclosed room. It is at once the ambition and the despair of ventilating experts to bring about such a condition. It seems to be impossible even to account for it.

The microbic poisons which air sometimes contains are by all means the most directly dangerous impurities which are likely to be present. They are the inciting cause of tuberculosis and pneumonia, which, together, produce more deaths than any other disease or group of diseases to which man is liable. The forms of sickness which are transmissible by air include nearly

every contagious and infectious disease which occurs in our northern climate, except the disease which has the distinction of being named bad air, or malaria.

How disease germs get into the air, how long they survive and how they fasten their infinitesimal personalities upon their unwilling hosts, is a subject of fascinating interest, but one which we can notice here only in the briefest terms. Everything is not yet known about this subject, by any means. A few facts, readily understood, are worth keeping in mind for the sake of the simple precautions to which they point.

The sputum of persons suffering from respiratory affections contains the infectious germs of their diseases in large numbers, and it is desirable that this material shall at once be rendered inert by disinfection, preferably by burning, in order that its poisonous nature shall be destroyed. In a dried state these germs may persist for weeks, although it is doubtless the fate of most of them to perish under such natural influences as desiccation and sunlight within a brief time.

It seems unnecessary to mention the fact that the sputum in tuberculosis and in pneumonia may remain capable of producing tuberculosis and pneumonia when inhaled by persons who are in a receptive condition. And yet that point has been disputed. Evidently the crusades which the tuberculosis experts have been making have not converted everybody. In experiments which I have made I have found that the germ of pneumonia may remain viable for twenty-one days when kept indoors, and be destroyed out of doors, in the streets, within four or five days.

It is not considered, however, that tuberculosis and pneumonia are most often contracted by breathing germs which have been dried and raised from the floor or the street in the form of dust. Hygienists are coming to the opinion that the destruction of most species of pathogenic bacteria proceeds rapidly outside of the favorable environment of the body, and that the transmission of disease germs from person to person generally takes place in ways which are comparatively short and direct. This view is reasonable and reassuring and goes far to compensate for the disquieting results of some recent investigations, which show that bacteria may be projected into the air from wet surfaces and under favorable conditions of temperature and moisture retain their normal characteristics for considerable periods of time. For example, sewer air has recently been found to, at times, contain bacteria which have become separated from

the sewage by splashing, by the bursting of bubbles and by the alternate wetting and drying of exposed surfaces.

If any one cares to get some recent facts in regard to that subject, I would refer him to the researches of Andrews for the Local Government Board of England, their last report being just issued. You are, of course, also familiar with Professor Winslow's work in that direction in Boston.

More important to most of us is the danger of germs thrown into the atmosphere by persons in the acts of coughing, sneezing and speaking. It has been found that in these natural and apparently innocent performances minute particles of saliva are ejected in great number, and that these droplets often contain bacteria. The moisture soon evaporates, leaving the germs free to keep afloat in air currents or gradually subside like motes of dust. Cough spray, as this fusillade of germs is called, may be highly poisonous, for not only are the bacteria which it contains thrown into the air in a perfectly fresh and virile condition, but they are relatively concentrated. Fortunate it is that so few of the countless species of bacteria which exist are capable of causing disease, yet the fact that the mouth is the normal habitat of at least a half dozen kinds of germs, and is sometimes the abiding place of diphtheria bacilli and other pathogenic species, considerably modifies the comfort which we can take in this reflection.

Closely associated with the bacteria in the causation of disease are the solid particles which air contains in the form of dust. A committee to which I happen to belong was appointed by the American Public Health Association to draw up standard methods for the analysis of air, and reported that the physical properties of the atmosphere are of more consequence to health than the chemical or bacteriological constituents, meaning thereby to place emphasis upon the importance of temperature and humidity, and especially upon the presence of dust, which contaminated air often contains.

Dust is directly or indirectly the greatest enemy of man. Aside from the enormous cost involved in the continuous warfare which is waged against it for the sake of mere cleanness, dust is dangerous to breathe. It is dangerous to breathe, not so much on account of the microbes which it contains, as because it is dust. Physiologists assert that nothing so predisposes the delicate structures of the nose, throat and lungs to invasion by microbes of respiratory diseases, and we can all bear testimony to the irritating and aggravating effect which a dust-laden atmosphere

produces upon the sore throats and colds which most of us experience every winter.

It is probably the very commonness of the dust evil which makes us so indifferent to it, as we must frankly confess ourselves to be. We forget that it is composed of the offscourings of our bodies and the wear and tear of our clothing, habitations, shops, factories and streets, not to mention the comminuted refuse of our kitchens and the desiccated excrement of horses upon the public highways. We are too indifferent to the way in which it floats in and out of our houses and contaminates the food we eat, the water we drink and the air we breathe.

I have here a report of a rather unique investigation made by a Western physician, Robert Hessler. It was printed in *American Medicine*, March 4, 1905. Hessler got the idea that there was a relation between dust and patent medicine advertisements, and he set to work to test his theory. He examined the newspapers from a good many cities throughout the country, and at different seasons of the year, and he found that at those seasons when there is most wind, and in those cities where there is most dust, the patent medicine advertisements were most prevalent. In some cities he found that one eighth of the total space of the whole newspaper was taken up with advertisements of patent medicines, nearly all of which were obviously intended to relieve people from the effects of dust, and yet not one of those advertisements mentioned dust. Hessler, being a physician, and a rather careful-thinking man, was able to examine the symptoms which the patent-medicine men described and was able to identify them with the symptoms of the dust diseases. In that way he established the theory that the sale of patent medicines was largely influenced by the dust of cities.

I will read you merely a paragraph from Hessler's report:

"I have a variety of newspapers from my own state, Indiana, and from different states and foreign countries, which I have marked at the head. For Indiana newspapers, the total advertising space varied from 2.5 per cent. to 14.5 per cent. The dust advertisements varied from 1.1 per cent. in a comparatively clean city up to 10 per cent., and even more, in a dusty city. It will, of course, be understood that in a clean city the percentage should be but a fraction of 1 per cent., and this we find realized in some clean cities of the Old World."

Sanitarians have given much attention to dust, and have divided it into several classes according to its harmful effects upon the human organism. In the dusty trades, so-called, the

most destructive dusts are those whose composition is most unlike the soft and yielding structures of the respiratory apparatus. The grinding and polishing of metals, and the cutting of hard stone, are, because of their dust, among the most hazardous occupations in which a person can engage. "Grinders' rot" is a name popularly employed for the tuberculosis which commonly affects knife grinders before middle age. Pneumokoniosis is a longer and more scientific term by which the medical profession designates diseases of the lungs brought on by dust of whatever kind.

There are many dusty occupations, each with a startling mortality peculiar to itself. Upon investigation, the immediate cause of death is always found to be the same — tuberculosis and pneumonia. The direct cause of death is disease contracted from germs thrown off perhaps by a fellow workman; the indirect cause is a pair of lungs which have lost their normal resilience and peculiar spongy texture and have taken on a hard consistency and dull, somber hue from the dust which they have absorbed. The lungs of coal miners are black; the lungs of men and women who have lived for some years in cities are gray, and the lungs of country people are a bright, healthy red.

I should say a word here with regard to the smoke evil, which the United States Geological Survey has estimated costs in one way or another as much as $600 000 000 a year to the people of the United States. Campaigns against smoke appear to have had very ancient origin. Several hundred years ago laws were passed in England to restrict the burning of very smoky coals, and to-day there are laws in effect in many English cities, — Liverpool, Manchester and Sheffield, for example, — which restrict the amount of smoke which may be produced from a given chimney to a fraction of the time. For example, a man with one boiler is allowed to have a chimney which smokes two minutes in the hour.

One of the most ingenious ideas for the restriction of smoke seems to be American. There is a commercial firm which goes about and offers to install an anti-smoke furnace in your establishment. You pay this firm from the amount of money which you save in the consumption of coal over the ordinary method. The name of that firm was recently mentioned at the American Public Health Association convention by the celebrated expert in tuberculosis, Dr. Knopf, who strongly advocated the abolition of smoke, or at least its repression to the lowest terms, as a public health measure.

Such being some of the conditions of contaminated air, let us glance for a moment at their remedy. We have found that the contamination of air, whether chemical, microbic or particulate, is due to its employment in some way for the use and convenience of man. Air becomes polluted just as water becomes polluted. In each case a fundamental requirement of sanitary science is ignored. From its controlling importance and universal application we may term this requirement the cardinal law of sanitation. This law demands that waste products shall be carried promptly from their source, kept always within control and be inoffensively disposed of.

It is much more difficult to observe this law in dealing with air than with water, and in no branch of sanitation will it be found possible to obey it perfectly. It is, nevertheless, our duty to keep its provisions prominently in mind, for no substantial success can be accomplished otherwise.

If the waste products of our furnaces and our factories were to be kept under control until they were utilized or otherwise destroyed, consider for a moment the immense saving in money and human life which would result. If persons sick with the lesser respiratory diseases, not to mention consumptives, were to isolate themselves as much as practicable, or, at least, refrain from visiting crowded assemblages, consider the enormous saving in life and health which would follow. If the filthy dust of our streets were to be kept from our lungs by efficient methods of street cleaning, consider the progress in decency and order, not to mention health, which this reform would accomplish.

The conservation of health has no better field for effective operation than systematic warfare against dust. With one notable exception, the use of oil on thoroughfares and railroads, no new method of combating this evil has been developed by sanitary science in recent years, while the quantities of dust produced and the harm which it has done have enormously increased with the growth of our cities. As matters stand, the greatest dust scavenger is the atmosphere. Into it we cast the dust of our houses with the same heedlessness with which we dump our sewage into the water courses. We do not stop to think that this air must serve to ventilate our dwellings and shops, and the lungs of our children and ourselves.

Speaking of pure air, Alfred Russel Wallace has said:

"This is the one great primary essential of a people's health and well-being, to which everything should, for the time, be subordinate. This is the gospel which should be preached in

season and out of season till the nation listens and is convinced. Let this be our claim: Pure air and pure water for every inhabitant of the British Isles. Remember, we claim to be a people of high civilization, of advanced science, of great humanity and of enormous wealth."

It has been beyond my limited capacity to-night to cast about my remarks all the qualifications which an exacting audience might require on this subject. I have spoken of the desirability of washing streets. I should have preferred if your invitation had come to me to speak about street-cleaning rather than on what is sometimes termed "air-sewage," and I should have preferred that my book on "Street Cleaning" had been mentioned when your chairman introduced me, instead of the one on "Air and the Ventilation of Subways."

I am a strong advocate of flushing streets, but not of flushing them as we often see that operation performed in this country. The way in which we customarily do that work is wrong. A better and more economical method is employed in London, for example. There the material to be flushed away is first made thoroughly wet. The streets are sometimes sprinkled twice to lubricate them. They are then flushed by means of hose in the hands of intelligent workmen.

I have said, perhaps without the approval of some of my hearers, that men, women and children who are suffering from the lesser respiratory diseases should stay away from crowded assemblages. I think this precaution is a matter of much importance. It is good for the person who stays away, and better still for the others. It is a common thing in New York when traveling back and forth in the overcrowded public conveyances, — and I think we get a pretty good example of how overcrowded they can be, — to see men standing and coughing directly down into the faces of those who are so fortunate, or unfortunate, as to have seats. The result is often to transmit the germs of respiratory diseases in the most direct and most dangerous manner.

Most of the pictures which I am going to show you were made in the investigation which I had charge of some years ago into the condition of the air in the New York subway. When the subway was first opened, there was a good deal of complaint as to the condition of the air. The subway grew hot and there were unpleasant odors. Some more or less scientific people made a few quick-and-easy determinations of the oxygen and carbon dioxide in the air, and published alarming reports in the newspapers. Professor Chandler, of Columbia University, made

some careful examinations of the carbon dioxide, which were reassuring enough for him and many others, but the Rapid Transit Railroad Commissioners were not fully satisfied. They held the view that here was a great experiment. The subway was certainly uncomfortable. Something was the matter with the ventilation. Was the air dangerous to breathe? If the air was bad and could not be made wholesome, there would be no more subways built. The importance of this question was considered great enough to warrant thorough investigation. I was asked to make the investigation and did so.

The temperature and humidity were determined. There were 50 000 determinations of the temperature and humidity. The oxygen was estimated; there were 80 determinations of oxygen. The carbon dioxide was determined; there were 3 000 analyses of that. The numbers of bacteria were determined; there were about 2 500 bacteriological examinations. The dust was analyzed. I found the problem to be largely one of dust so far as health was directly and seriously concerned.

I found at the outset that the ordinary quick-and-easy methods of analysis employed in most ventilation work were not suitable for this case. And so the most accurate determinations which it was practicable to make on a large scale and under the difficult conditions of subway traffic were employed.

It was only by the most refined methods that we could detect any difference between the oxygen in the subway and that in the outside air. The difference averaged only about $1\frac{1}{2}$ parts of carbon dioxide per 10 000 parts of air. It was almost incredible that such a slight difference should exist while the air in the subway was so unpleasant, yet the fact could not be disputed.

It was difficult to get samples. It was desirable that they should be collected, as far as possible, away from people. So I had the sample bottles put in a basket with a pump and a ther-

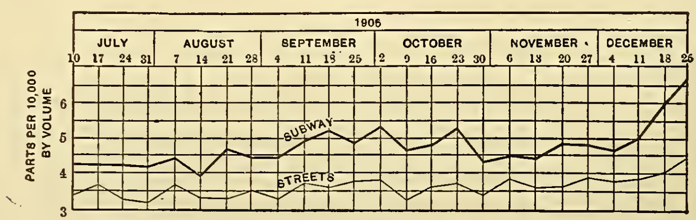

FIG. 1. Weekly average carbon dioxide in the subway and streets from July 10 to December 25, 1905. The number of determinations included in this figure was 1 772.

mometer. The investigator appeared to be a young man proceeding to market. He would go to the part of the subway previously determined on, await his opportunity and then take the cover off the basket sufficiently to insert a rubber tube. Then with the air pump he would pump air through a flask until the flask was filled with the air to be analyzed. I found we could get a reliable sample in that way and in that way alone.

Fig. 1 shows some of the results. There were about 2 000 analyses averaged to get the figures from which these curves were made. The amount of carbon dioxide in the air of the subway is shown by the heavier upper line; that in the streets by the lighter line below. Note the correspondence between the rising and falling of these two lines.

You see the observations extended over several months. I found that there was a difference in the amount of carbon dioxide in the air of the streets at different hours of the day. Rush hours in the subway always gave larger amounts of carbon dioxide than other hours. And, curiously enough, the rush hours in the subway appeared to be the rush hours in the streets. Apparently, the air in the streets was affected by the great numbers of people in them.

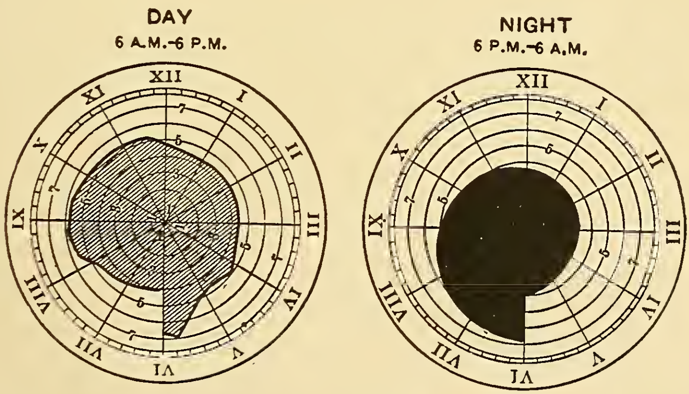

FIG. 2. Hourly variations in the amount of carbon dioxide in the air of the subway. Averages of 1 244 analyses.

A MEMBER. — What caused that very great rise in December?

DR. SOPER. — A large increase in the number of people using the subway and streets. There were more people than usual in the city. It was the Christmas season.

There were regular variations in the chemical condition of

the air at different hours of the day and night. At six o'clock in the morning the carbon dioxide in the subway was at a minimum. It then increased rapidly up to the end of the morning rush hour. You understand this circular, clock-like diagram? (Fig. 2.) The amounts of carbon dioxide are laid off from the center on the radial lines, each of which represents an hour. From the end of the morning rush hours, there was a gradual reduction until just before noon, when the reduction ceased and

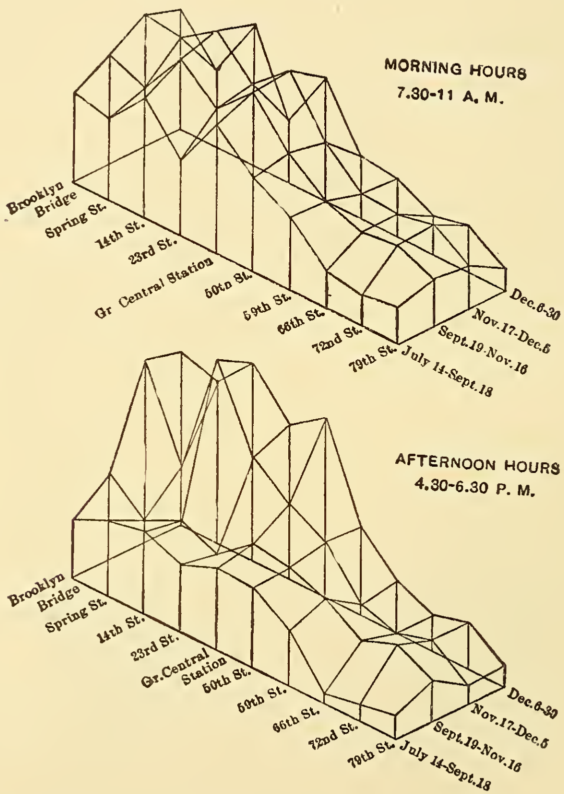

FIG. 3. Carbon dioxide at different stations at different seasons during the hours of maximum travel in the morning and afternoon.

there was a slight increase. The increase was apparently due to the fact that there was a slight rush of people who used the subway about noon in the shopping district. After noon there was a progressive reduction down to the beginning of the rush hours of the afternoon, when there was a decided increase. From that time there was a pretty constant reduction until morning.

MEMBER. — Why was there so much more carbon dioxide at six o'clock at night than during the rush hours of the morning?

DR. SOPER. — Because more people traveled at that hour than at any time in the morning. The crowding was much greater. The morning rush hours were longer. Most of the people who went to business between seven and nine wanted to get home as soon after six as possible.

Fig. 3 shows a compound diagram which may need a word of explanation. We have here the amount of carbon dioxide found at the different stations. The subway, you know, is 20 miles long, and the most interesting part of it, from the standpoint of ventilation, is between Brooklyn Bridge and Seventy-Ninth Street. This diagram represents the conditions between those two points. The amount of carbon dioxide in the air at the different stations for the period from July 14 to September 1 lies along the lower broken line. Now, later in the season, when more people were traveling, there was much more carbon dioxide at those stations. We have this fact shown on another broken line. Later, in November, when the heat began to abate and more active business conditions led more people to take the subway, there was a further increase in the amount of carbon dioxide, and so on until the end of December. There is one diagram for the afternoon hours and one for the morning hours. For each station you will find on this diagram the amount of carbon dioxide for the months covered in the investigation.

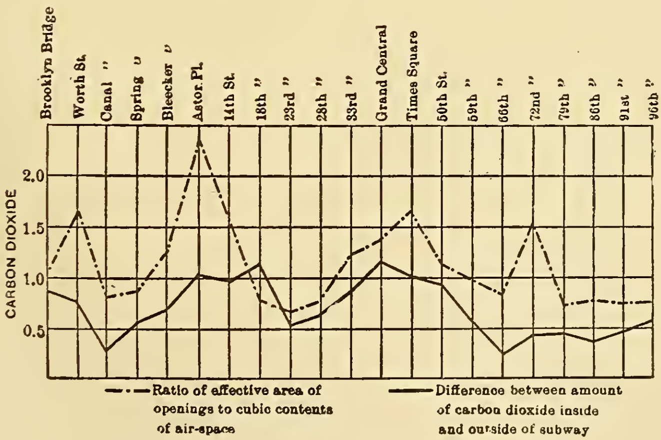

FIG. 4. Relation between the chemical condition of the air in the subway and the ratio of the effective area of the openings to the cubic contents of the air space at different stations.

One of the most useful results of the whole work is illustrated in Fig. 4. The point illustrated is that a distinct relation existed between the number of openings to the street and the condition of the air. I need not go into the details. I think you can follow the diagram without my aid. It led me to the opinion, which I have since been able thoroughly to confirm, that the New York subway and other subways of its kind will ventilate themselves if they are given a chance. The New York subway did not have a chance, and the Paris subway did not, for the reason that it was too tightly enclosed for the air to move in and out with the requisite freedom.

It is not necessary to put fans into subways like the New York subway. In fact, it is doubtful if fans, even on the largest scale practicable, will produce material improvement, except immediately at the points where, for example, outside air is pumped in. Fans will not improve the air sensibly for any considerable distance. This was proved by my investigations. But if you will give the subway openings enough, it will breathe of itself. The breathing bears a rather close analogy to the breathing of animals.

The subway in New York has been materially improved by providing blow-holes through which the air set in motion by the trains can move in and out. I have said the need of so much opening was not evident at first.

Bacteriological examinations of the air were made. Professor Sedgwick devised filters for air some years ago, and it was partly upon his plan that our filters were devised. They are small tubes filled with sand and plugged with cotton at both ends. We fastened two filters in tandem on a rubber tube, which was connected with a well-made and carefully operated pump. The number of strokes of the pump gave us the quantity of air passed through the filters. In passing through the filters the air parted with its germs. After filtration the filters were taken to the laboratory and there dealt with in a way commonly employed in bacterial analysis.

MEMBER. — Did I understand you to say that the fans made no improvement?

DR. SOPER. — I said the fans did not materially improve the general air in the subway. The blow-holes did. Before the time the fans were put in, the subway was most enclosed, it is probable that the air was renewed once every half hour. The amount of renewal after large sections of the roof were opened was very great. It wasn't possible to tell exactly how often the

air was renewed, for the reason that the number of people traveling in the subway was not known by the city. There was no census of travel for a long time after the subway was put in operation, and none until after my investigations had been completed.

The air pump referred to could not always be used. It took a long time to operate it, and aroused more curiosity than anything else we did. So we sometimes employed the cylinder shown in Fig. 5 to serve as an air pump. You see it is a brass cylinder provided with a vacuum gage and two stopcocks. To get it ready, the cocks were closed and the air was exhausted from the cylinder. The cylinder was then put into the valise which you see in the background, and the investigator carried this innocent-looking baggage to the point where he wanted to make an examination of the air. There he connected up his filters, through the side of the bag. When he opened the cock, the air rushed into the cylinder through the filters. We experimented in the laboratory until we knew accurately the quantity of air that flowed into the cylinder when we opened the stopcock, and reduced the pressure within to the extent indicated on the gage.

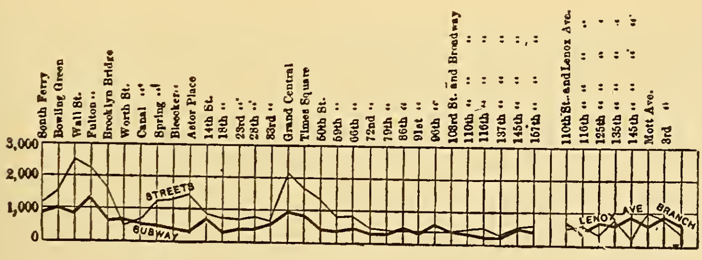

FIG. 6. Average numbers of bacteria which settled from the air upon each square foot per minute, at different subway stations and in the streets, and were subsequently counted. The number of samples represented is 2 753.

In Fig. 6 you see the results of determinations of the numbers of bacteria at the different stations throughout the length of the subway and in the streets overhead. There is a general correspondence between these two sets of figures. The average of all the analyses shows that about half as many bacteria were found in the air of the subway as in the air of the streets. The numbers of bacteria varied with a good many circumstances, one of them being the number of trains and consequently the amount of air moving in the subway.

The accompanying table tells its own story and shows the effect of improper methods of cleaning. The porters swept the platforms without first moistening them, and this greatly increased the numbers of bacteria in the air. The movement of the trains kept the bacteria in the air because the movement of trains set the air in motion, and the dust particles, which we will consider later, were kept afloat also by the air currents.

TABLE. — Effect on the Numbers of Bacteria in the Air of the Subway produced by sweeping the Platforms improperly.

Place.	Time, A.M.	Microörganisms per Cubic Meter of Air.		Ratio of Bacteria to Molds.
		Bacteria.	Molds.	
Fulton Street Station, South End, west platform. Remote from openings to streets	10.25	4 900	100	49 : 1
Porter began sweeping near by	10.41	13 200	50	264 : 1
Still sweeping, but farther off	10.57	8 100	0	......
Still sweeping, middle of platform	11.12	8 500	0	......
Average	.....	8 600	38	226 : 1

It was very difficult to devise a plan for determining the quantity of dust in the air. The difficulty lay in the necessity of examining a large volume of air. The amount of dust was small to separate and weigh with accuracy. And so the apparatus shown in Fig. 7 was employed. It consisted partly of an ordinary Root's blower, adjusted so that it drew air through a gas meter. The gas meter was carefully tested and found to work with sufficient accuracy in this manner. A filter was attached to the gas meter, so that, when this pump was operated, the air passed down through the filter to the meter. The filter was composed of sugar. After a sufficient number of cubic feet of air had been passed through the filter, the filter was disconnected and taken to the laboratory. There the sugar was dissolved in water. The water was then filtered and the solid particles were dried and weighed.

Fig. 8 shows samples of different kinds of dusts. One kind was collected from a hotel. You will notice the fibrous character of it. You don't need a microscope for that. The unaided eye can see how it differed from the more broken granular street

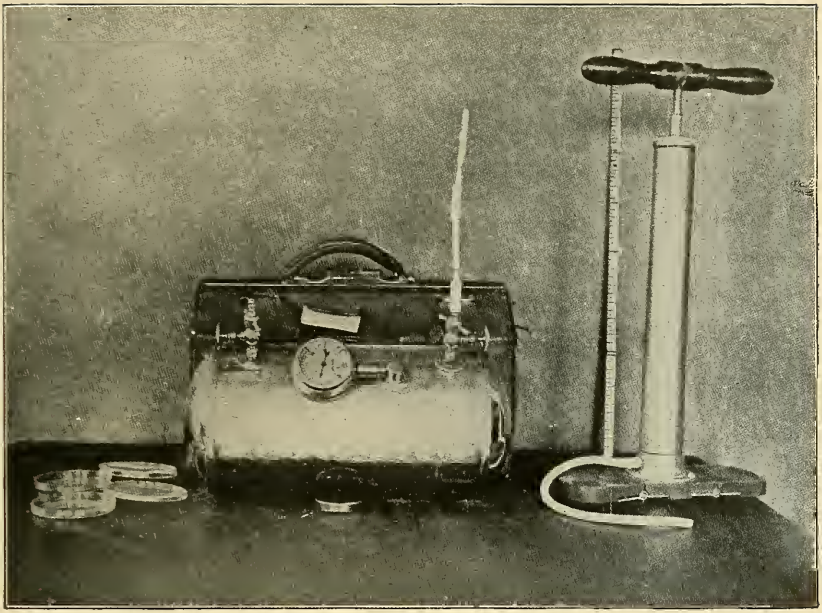

FIG. 5. Vacuum cylinder with sand filter attached, air pump and other apparatus used in collecting bacteria from air in crowded places. In use the cylinder fits inside the handbag.

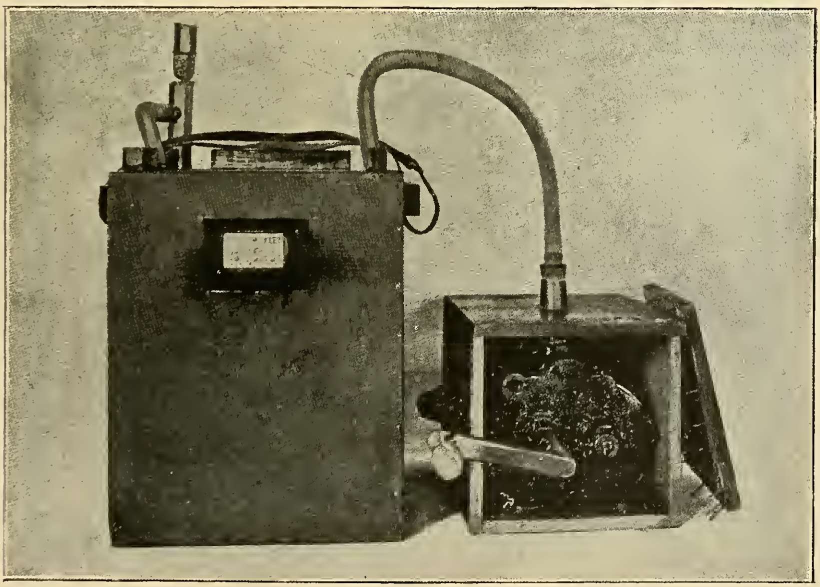

FIG. 7. Apparatus for determining the weight of dust in a measured volume of air. To the right is an exhaust blower operated by hand. A gas meter is on the left. The air passes through a filter of sugar shown on top of the gas meter.

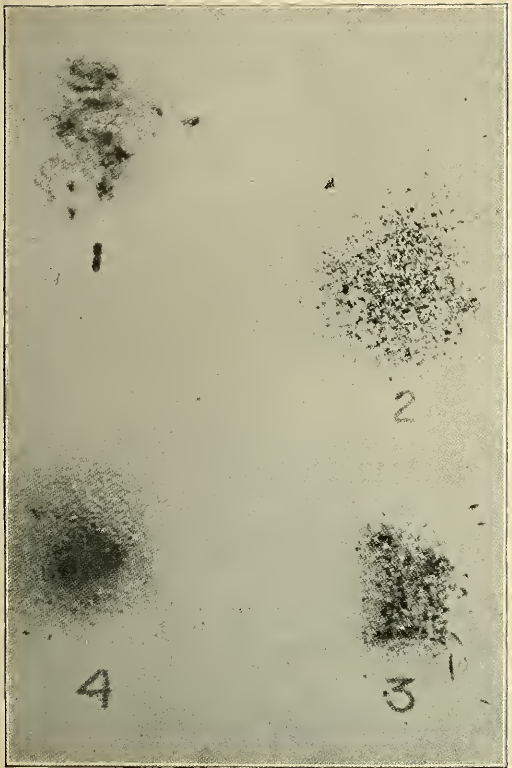

FIG. 8. Physical appearance of dusts. 1. From a fashionable hotel. 2. From the street (Broadway). 3. From a popular theater. 4. From the subway.

FIG. 9. Magnetic field formed by subway dust. A piece of paper was laid on top of a common horseshoe magnet and subway dust was sprinkled on the paper.

dust shown. Below is a specimen of dust from a theater and a specimen of subway dust.

The subway dust was of a peculiar fineness. Unfortunately, the sharp, angular character of the particles is not as apparent as I'd like it to be. Many of the particles were sharp, flake-like and angular. When the dust was put upon a piece of paper, horizontally placed, and a horseshoe magnet was put under the paper, a few taps on the paper caused the dust to take the form assumed by the magnetic lines shown in Fig. 9. This at once suggested that the dust was composed of iron and steel. So we analyzed the dust and found that to be true. There was over 61 per cent. of iron in it.

The iron in the dust was the cause of a good deal of anxiety. The question was whether the employees in the subway were engaged in a dangerous occupation. Were we to expect pneumokoniosis among the men? There was no special sickness reported, but this was not convincing. Even knife grinders and fork grinders do not show visible symptoms of pneumokoniosis. It takes years before the fatal effects become evident. When a grinder is forty years of age, he is considered an old man and is very likely to be attacked with tuberculosis or pneumonia. And I have heard men say at thirty that their time had about come.

The question, therefore, was, Are any effects from this dust visible among the employees of the subway? There was only one way to determine that, and this was to examine the men.

So I had one hundred men assigned for examination. Each had worked for a year at least in the subway. I then employed a number of physicians. They were all connected with the College of Physicians and Surgeons of New York in the capacity of instructors. I had these young men examine the employees.

Each employee was examined thoroughly. He was stripped to the waist. The examination took about twenty minutes for each man. The records of the examination were transmitted to me, and I set to work to find out from them if there was anything wrong with the men.

We found that 53 per cent. of the employees had dry pleurisy. But I was then as much in the dark as before. I couldn't get much information about dry pleurisy. I read every book I could find on the subject, I interviewed many capable physicians in New York, and I corresponded with some of your Harvard professors, but I was still completely at sea. And for

a long time I had no explanation to offer to the Railroad Commissioners.

I could not find out how prevalent dry pleurisy was among people of ordinary occupations. So I undertook to find this out. I had two hundred men representing many walks in life examined by the physicians — examined by the same physicians in the same way. In this manner I found that about 10 per cent. had dry pleurisy.

Evidently there was a marked excess of dry pleurisy among the subway men. At length I found it explained in their histories. A large part of the men had been steam locomotive engineers or firemen, and had suffered from ordinary pleurisy, and the dry pleurisy I found was the remnant, the scar as you might say, of the active pleurisy they had experienced before. It was a fairly satisfactory explanation.

But I would like to see the men examined again now that they have worked for a longer period of time in the subway. I should like to see the same men examined by the same physicians. In fact, such work ought to be a regular part of the administrative duties of every subway company and, in fact, of every enterprise where the health of employees is at stake.

Of the standard thermograph which was employed, we imported about twenty from Paris. It was at first a question what form of instrument to use. In order to answer it we set up a testing station and tried every well-known recording thermometer. The trials lasted about three months. We decided to adopt the Richard thermograph. It is the instrument which the Committee on Air Analysis of the American Public Health Association has adopted as standard.

The temperature and humidity determinations were made chiefly with the instrument called a sling psychrometer. It is not as well-known among engineers as it should be. It consists of two thermometers, twins in every respect. They are set upon a skeleton back and with the mercury bulbs extending considerably below the back. One of the bulbs is wrapped with cloth and in use is made wet. At the upper end of the back of the thermometer there are two links which attach the instrument to a handle.

One of the reasons why this instrument is not used more is that it is very delicate. Until the present time there has been no way to carry it about. When we started we had six or eight thermometers broken in the first two or three days. They cost too much to destroy at that rate, so I devised an aluminum tube

case in which the whole thermometer can be placed and fixed with a bayonet lock. The breakage was very slight after that. After the bulb is wet, the instrument is slung around the hand until each thermometer comes to a constant reading. Then the readings are taken in a notebook, and from suitable psychrometric tables the degree of relative humidity is determined.

A special instrument was used in the subway work, called a "konoscope." It is an invention of Professor Aitken. He is a Scotchman who, following some of Tyndall's ideas, set about determining the number of dust particles in the atmosphere. He devised a very complicated, very scientific and, in his hands, a very satisfactory instrument. But to make the determination of dust particles more universal, he devised the small konoscope. It is portable and I have found it extremely useful. The konoscope consists of two parts, a tube and a pump. The tube is about 2 ft. long. At one end there is a ground-glass disk which fits completely the opening of the cylinder. At the other end there is also a disk. The pump is permanently attached to the tube. The principle of action is simply this: The tube is filled with air by the pump. The stopcock is closed and then with one stroke of the pump the air is rarified. A miniature cloud is produced in the tube, and the density of the cloud is an indication of the number of dust particles present. The theory is that a cloud, or "rain," as Aitken calls it, forms with each drop collected about a dust particle.

The point was raised by one of the engineers representing the Transit Commission that, although the air at the stations was probably good according to my analyses, the air did not circulate between the stations. I wanted to test this theory, but it was too hazardous to send men between the stations to take samples of air. A good many laborers were being killed in the subway as it was. And so I devised this scheme for finding out the extent to which the air circulated between the stations. I got some quadruple extract of lilac and put a half pound or so of it in a can, and then with a pump we squirted a spray of perfume into the air. I had men at adjoining stations to note whether a change took place in the customary odor of the air. The men were supplied with watches which were compared later with the watch of the man who did the spraying to see how long it took the odor to travel from place to place. I found that the air went from station to station almost as fast as did the trains. Apparently, a train moving in the subway, although it didn't by any means close the section, forced a column

of air ahead of it almost as large as the section. The work was checked in various ways. I can recommend this simple scheme of odor tests as an excellent way of studying air currents.

I was speaking a while ago of the air of enclosed spaces never being as fresh to the senses as outside air. I had occasion to make some practical experiments in that direction some years ago. I had to take charge of the suppression of an epidemic of typhoid fever of about 600 cases. The hospitals were overfull. In fact, one of the largest hospitals was so crowded that an epidemic of erysipelas had broken out in it. So I told the people they ought to have larger and better hospital accommodations. They said they had no building in the town to use except the new high school, just finished at a cost of about $100 000. We decided to use it, although the Board of Education made serious objection.

In this building we had 97 cases of typhoid fever, and there was but one death. That is a very low case fatality. The schoolrooms were turned into wards. There was one ward kept always ready for a surgical operation, in case a physician thought one was necessary. But the point I want to invite your attention to is this, that the building was kept in an extremely clean condition. We did not attempt to disinfect the floors. We did not attempt to fumigate. With the exception of a small place in the cellar where we used carbolic acid, there was no disinfectant used that produced an unpleasant odor. The scheme of ventilation for the high school, so far as artificial ventilation could be devised, was thoroughly good. But it wasn't used. We had the windows opened. The result of the cleanness and the ventilation was that any one could come into the hospital and move about without that depressing sense one gets when breathing the air of most hospitals, large and small.

Physicians customarily say that there is a great advantage to their patients in opening windows and getting a great flush of air through a sick room because of the added amount of oxygen which the patient gets. I hope I have expressed my view, and I think it is pretty well substantiated by analysis, that you don't get more oxygen under those circumstances than you do when you get fair ventilation. What you do get is a refreshing sense of feeling from the large volume of air. That I take to be one of the most valuable curative properties of air. And yet, as I have said, we can't analyze or measure it.

The President. — I am sure Dr. Soper will be glad to answer any questions.

A MEMBER. — I'd like to ask Dr. Soper in regard to dust layers that are used both in the streets and in the interior of buildings and offices, whether they are a benefit or not.

DR. SOPER. — I believe the effect of such layers is a very considerable benefit. I shouldn't want to be asked to mention the ones I think best, there are so many proprietary compositions, but it seems to be the belief in Europe that it is very desirable to lay the dust by such preparations as you have in mind.

A MEMBER. — I'd like to ask Dr. Soper whether the character of the pavement in the street made any difference in the air.

DR. SOPER. — I did not take that into account. There may be data collected during the investigation that would be informing on that point, but the data have never been examined to that end.

A MEMBER. — I'd like to inquire of Dr. Soper whether there is any special reason for the large percentage of iron shown by one of his diagrams — I think it was in the air of the subway.

DR. SOPER. — You want to know why there should be so much iron in the air of the subway?

A MEMBER. — Yes. Was it from the rails?

DR. SOPER. — No, sir. The iron dust in the subway was due chiefly to the wear on the brake shoes. I found that there was produced in the subway one ton of dust for every mile every month from the brake shoes alone. At about the same time I estimated there was produced about a ton a mile a month on the elevated roads of New York. I did not take into account the wear on the rails or on the wheels. But so great was the wear on the rails in the subway that the Interborough Company had a special steel made for the rails. They got tired renewing them.

The consumption of iron in New York, and the resolution of the metal into dust, is the most remarkable, most disfiguring element in the city air. If you look at any of our white buildings, such as the Metropolitan Life Insurance Building on Twenty-Third Street and Fourth Avenue, you will see it is stained from top to bottom — stained yellow. It is stained much more deeply at the bottom than at the top. If you examine the Chemical Bank Building, on Broadway, you will find the same is true. But there the stain is even more marked.

Our City Hall itself was cleaned by sand-blasting about three years ago, and when I entered it to-day I was struck by the deep orange color of the lower part of the building. Now, that is in the center of a little park. The iron dust produced by the

wear and tear of trolley cars on the surface, of the subway nearby and of the elevated road, not to mention the great amount of iron dust from machinery and from horses' shoes, had been carried by the air to the City Hall, and there, by the aid of moisture, had become resolved into a yellow stain.

When the Metropolitan Life Building began to be stained, I discussed the question with some of the engineers and architects of that building, and suggested to them the cause of the trouble. It is one of the largest buildings in the city, and one of the most ornamental. Their view was that there was iron in the marble. But I went to Tuckahoe, where the marble came from, and found that houses had been built in the country not far from there of the same material and had stood many years without any stain. And then I collected dust from the Metropolitan Building — collected it on nearly every floor up to the top, which is a great distance from the sidewalk. I always found iron particles in the dust, and always in sufficient amount to account for the results. It would be an interesting thing for any one here who is at all concerned about dust, and curious to know how much iron there is floating around in the atmosphere he breathes, to scrape up a little dust, — perhaps from his bookcase, or somewhere else in his home or office, — take a common ten- or fifteen-cent horseshoe magnet and pass it over the dust. Or, preferably, if the dust is scattered on a piece of paper, take the magnet and pass it back and forth under the paper. In the last case, with the magnet moving under the paper, the sharp eye will see some of the particles rearing themselves on their hind legs, so to speak, and waving back and forth in accordance with the amount of magnetic attraction beneath.

I have never found any dust in the city of New York that has not had iron in it. Unless dissolved by long-continued exposure to the weather, the particles retain their sharp, blade-like form.

There is a way to prevent much of the iron dust of the subway, and that way has been employed in the Central Underground of London. The Yerkes Tubes, of London, so called, have given up iron brake shoes and use a fiber brake shoe. These brake shoes are economical and prove an excellent remedy where such an amount of disfiguring dust is produced as in the New York subway.

Mr. Harrison P. Eddy. — I was very much interested in Dr. Soper's talk and the slides he has shown us. During the discussion, one or two points occurred to me which he did not

touch upon, and which I think are particularly interesting and of considerable importance.

First. The smoke and fumes emitted from gasolene automobiles in the public streets are at times very dense, and a source of much annoyance to other people using the public thoroughfares. The inconvenience thus caused a large number of people is of sufficient importance, I believe, to warrant a thorough investigation of this subject for the purpose of finding reasonable methods of mitigating the discomfort which, in some instances, certainly approaches a nuisance.

Second. Of even more importance is the question of the effect of the fumes from the gasolene car upon the health of people inhaling them. In several cases in this country, as well as abroad, experiments have demonstrated that comparatively large quantities of carbon monoxide are contained in the waste products of combustion from a gasolene engine. The poorer the combustion, the greater will be the quantity of carbon monoxide generated. Where the products of combustion are discharged into a closed room, as, for example, a garage, cases of illness presumably due to poisoning by carbon monoxide are known to have resulted. It would, therefore, seem very probable that sufficient carbon monoxide might be discharged into the air in our public streets, expecially those which are congested, and in which there are many automobiles, to affect the health of pedestrians and more particularly of people who are required to remain in the impure air for long periods of time, as, for example, chauffeurs, policemen, etc.

It would be interesting to know if Dr. Soper has himself, or knows of others who have, investigated the subject of the discharge of products of combustion from gasolene cars into the air of our public streets, and what the results of such investigations are, and whether methods have been devised for remedying the discomfort and the danger, if there is any, to the public health.

Dr. Soper. — I want to thank Mr. Eddy for bringing out that point. It has so aroused people in New York that a number of physicians, eighteen or twenty of the most prominent men in the city, have signed a petition asking that an ordinance be passed to stop it, that is, to stop the production of unnecessary, offensive gas from automobiles. I think they chiefly object to the unconsumed oil, and the waste and the unnecessary consumption of gasolene. I don't know whether much carbon monoxide is produced or not. If there is, there is a very substantial objection

to the fumes on that account, for there is no worse poison than carbon monoxide in the air. It is very much like carbon dioxide or methane, but is very poisonous on its own account.

I want to thank Mr. Weston, too, for laying emphasis upon the unpleasant smelling exhalations from the body. I believe that, just as truly as dust should be suppressed because it is dust, no less than because it is unwholesome, odors should be prevented because they smell bad. The odors come, as Mr. Weston has delicately suggested, from perspiration, from excrement of people who ought to know better and be clean. Odors often come, too, from clothing which has been hanging up near a cook stove. The most unpleasant odors of human origin come from the mouth — the mouths of persons who are neglectful of their teeth and persons who have catarrhal difficulties and certain digestional affections. Almost all of those afflictions can be corrected. The difficulty lies in the fact that persons who produce the unpleasant smells are often unconscious of them themselves. It is one of the lamentable facts of sanitary science that a man becomes accustomed to unsanitary conditions, indifferent, apathetic toward them.

A Member. — I'd like to ask Dr. Soper if he has noticed any increase in the dangerous element of dust by its becoming old: that is, as it grows older, it becomes more dangerous. I have noticed one thing in regard to old drawings, particularly tracings, that if they have been filed away they have a decidedly unpleasant odor that increases with age, while tracing cloth that has not been drawn upon in a similar situation does not have that odor. And I know of several cases of diphtheria and sore throats that I have thought could be directly traced to the opening up of these cases where plans have been filed for a long time and only infrequently opened.

Dr. Soper. — I am of the opinion, sir, that dust does not increase in danger with age, but decreases. Nearly all the pathogenic bacteria are believed to be destroyed under the conditions which they encounter outside of the human body.

But there is this to be remembered, that, as Mr. Weston has pointed out, the germs may be present and find a more suitable lodgment where dust is inhaled. I think you all know that the germs of many diseases are likely to be present in the mouths of many people here to-night. I have no doubt that one third of us have germs of pneumonia in our mouths now. The reason we don't get the disease is that we are for some reason immune. The immunity varies from day to day and from month to month.

A man can't count upon being perfectly free from danger to-morrow because he has escaped typhoid fever or diphtheria to-day. But that the germ of diphtheria is more often present in the mouths of people than was formerly understood is now an undisputed fact. Perhaps tending to reduce a man's resistance would be such effects upon his central nervous system, reflecting upon the tissues of his throat, as the opening of maps and the experiencing of the unpleasant sensations produced by the dust, for the central nervous system is believed to exercise an important part in the matter of immunity.

A MEMBER. — One other question along the same line. Isn't the effect of sneezing that we all experience a saviour, we might say, from disease in a great many cases; that is, doesn't the involuntary act of sneezing tend to throw out the particles that have obtained lodgment in the mucous membrane of the nose, and therefore, rather than restrain it, ought we not to let it come and receive it in the handkerchief, instead of letting it get into the air to the injury of other people?

DR. SOPER. — I believe sneezing, like coughing, is good for the person who does it, but bad for others. There is no reason why a man should not cough or sneeze into a handkerchief, if he has one. You notice when little children sneeze, their mothers say that is a healthful sign. But there is one thing in the use of the handkerchief against which I'd caution any one who wants to be careful. Don't sneeze into a handkerchief and later shake the handkerchief in air which people must breathe.

[NOTE. — Discussion of this paper is invited, to be received by Fred Brooks, Secretary, 31 Milk Street, Boston, by Nov 1, 1910, for publication in a subsequent number of the JOURNAL.]

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THE PRACTICAL QUESTIONS CONCERNED IN THE COLLECTION AND DISPOSAL OF MUNICIPAL WASTE.

BY WILLIAM F. MORSE, MEMBER OF SANITARY SECTION.

[Read* before the Sanitary Section, Boston Society of Civil Engineers, March 30, 1910.]

YOU have done me the honor to ask me to say something on the general subject of garbage and waste disposal. This question is so wide in its scope as not to permit any extended discussion of the whole topic at the present time. Hence, I prefer to limit it to the consideration of the engineering problems involved in the past and present methods and apparatus in use in America for the treatment and disposal of municipal waste.

The engineering side is rapidly coming to the front in all the larger cities, and the future will decide whether this matter will be put into the hands of engineers for examination, advice and assistance, as is customary in other lines of municipal engineering, such as water supply, sewage treatment and disposal, and electric lighting. Heretofore, waste disposal has been largely in the hands of health officers, committees of council and others, gentlemen who are earnest, conscientious and learned in their professions and occupations, but who know but little concerning the problems to be solved, and during their limited terms of office cannot be expected to give the necessary time and atten-

* This paper was illustrated by about seventy-five lantern slides, most of which cannot be shown in the cuts. The author wishes to make acknowledgment to the Society for Municipal Improvements and the *American City* for the use of many of the cuts which accompany this paper.

tion for a thorough consideration of the subject. Consequently a large number of failures heretofore made are due to the fact that there has not been a sufficient amount of engineering knowledge applied to the matter.

There are a large number of slides showing what has been done in the last twenty years by various methods and apparatus, but the time at my disposal will permit only the presentation of a résumé of the history of crematory building in this country during the period referred to.

Beginning with the consideration of the material with which we have to deal, the classification made by the American Public Health Association, as applied to American municipal waste, has been universally adopted.

Municipal waste is divided into two general divisions: *Organic waste*, which includes garbage, or exhausted food matters; night-soil; the bodies of animals; the refuse from slaughter-houses and abattoirs; in short, every substance which by nature is liable to decay and putrefaction.

The second division comprises *inorganic waste*, including ashes; and all forms of combustible substances, under the general head of rubbish or refuse. Properly speaking, street sweepings should be included under the first division, but these are usually handled by the town itself, and are not included under the term *municipal waste*.

We have then to deal with only three forms of waste matter, — garbage, ashes and rubbish, or light combustible refuse.

In the early days of a town it was not difficult to get rid of waste matter; a householder was allowed to keep a pig, and later, as the town grew in population, these pigs were carried outside the town limits and fed with the town's garbage, while the ashes were carted off to unoccupied ground, and were used for building up sites for houses, or for the extension of streets. The townspeople got rid of whatever was obnoxious as best they could, and there was no talk of sanitation. As the town grew still larger it became necessary to regulate the waste collection and disposal, which brought into service the license system, by which men were authorized to collect the waste and receive their compensation directly from the householders. Under this method the householder paid at the rate of three to five dollars per year to have his premises kept free from offensive matter, and the burden became somewhat onerous to those who employed it, as it was too much for the service, in one way, owing to the fact that it was not obligatory upon any one, and

that those who assumed it felt committed to continue it, but it was not binding on those who did not choose to accept this means.

The work was then undertaken by a contractor, who assumed all responsibility of collection and disposal, at the lowest price, and who gave the least possible service for the money. This is the usual way in which all garbage and rubbish is handled in the largest number of towns and cities in this country. It is not an entirely satisfactory method, since it involves the expense of inspection and oversight, and the investigation and adjustment of endless complaints which always accompany poor service performed at the cheapest possible rate. The only advantage is that it relieves the householder. It may be said to be the typical American way of doing the work.

Municipal service is the fourth way. The town provides its own equipment and employees, itself doing the collection and disposal work. This is at a somewhat greater cost than by contract, but with efficient superintendence it is far more satisfactory than any other. The responsibility is centered upon the chief of the bureau, and by him distributed through his assistants, so that unsatisfactory work can be noted and corrected without loss of time.

An inland town had occasion to go into this matter and found that by the license methods the householders were paying five to eight dollars a year individually. It also found that, if the municipal system was adopted and the cost of the service assessed pro rata upon the property valuation, the expense would be approximately $1.64 per household per annum, or about three cents per week.

Connected with this matter of collection is the variety of carts and wagons used in the service. In most cases the carts are inadequate and unsatisfactory. A new idea in transportation of this offensive material is demonstrated by a recent invention which has been brought to my attention here in Boston. Briefly described, it consists of a can or cylinder with the capacity of one half to one ton; it is provided with a top, part of which is a hinged cover closing automatically, and opened only during the time that the driver is engaged in emptying the garbage cans. Its chief advantage is that of sealing the can during the intervals of charging, which prevents flies and other insects from getting in, and stops clouds of flying dust and ashes. When the cylinder is brought to the place of final disposal it is lifted from the truck, and the whole upper part of the can disengaged from the cylinder,

which permits its being dumped and cleansed without loss of time. This particular device seems to be worthy of investigation in connection with collection work.

Garbage Disposal by the American Crematory Method.

From the earliest days the method of satisfactory disposal of towns' refuse has been difficult to determine. About 1884 the leading American engineering papers printed reports of crematories used for the destruction of waste in English cities. A few descriptions were given of the apparatus employed. In 1885 the first recorded efforts to do likewise were made in this country. An officer of the United States Army, stationed at Governor's Island, New York Harbor, built a rectangular structure of brick having two interior chambers, floored with fire bars, and having inclined grates from the middle line of roof to the sides of the walls. Through openings in the roof he charged the material to be destroyed behind these grates, where it was held until dried out and consumed by the fire below. The gases and smoke passed to the chimney at the rear of the interior chambers. This furnace, afterwards known as the Government Garbage Crematory, was built at many government army posts, and the first example continued in use for about eighteen years.

This furnace was followed in 1886 and 1887 by others whose builders followed the lines of the English furnaces. The "Smith-Siemens" furnace at Wheeling, W. Va., using natural gas for fuel; the "Beehive" furnace at Allegheny City and Detroit, and the "Fryer" Destructor at Montreal, were the earliest forms. The invention of Mr. Andrew Engle, Des Moines, 1887, was the original American type which found greatest favor, and of which the largest number were installed in the ten years following. This was a rectangular brick structure, with a high steel or brick chimney, and with a covering house, approaches and platforms so arranged that the carts might discharge directly into the charging holes at the top. At the rear was placed the first or "primary" fire, the heat from which passed to the front end, over thick layers of mixed waste piled upon transverse bars. At the front end was placed a secondary fire, over which the gases and smoke from the combustion of the material on the bars passed on their way to the chimney, and, returning beneath these transverse bars, these gases heated the material from the under side. The waste was charged through ports in the roof, one of which was made large enough to receive the carcass of a horse or other large animal. The free water or liquids

passed through the transverse grate bars to the bottom of the furnace, where it was evaporated. The weak point in this construction was the transverse bars, or grates, first made of pipe, afterwards of pipe with water circulation for their preservation, and finally of a series of fire-brick arches, separated by a narrow spacing to permit the ashes to fall through.

The central idea of this invention was to burn the material placed on transverse grates by a heavy primary fire, and then to reheat and reburn the smoke and gases of combustion, with the assistance of the secondary fire.

This principle and form of construction was adopted by many other builders of crematories, and in the years following a large number of incinerators and crematories were installed. Incinerator was a term used by some builders. There were variations in the location of the secondary fire, and in the addition of other apparatus designed for the destruction of the smoke. The most notable departure from the original type was a return to the inclined grates of the government furnace, in one example. In this incinerator the walls and roof were of steel-plate, water-jacketed construction, which provided for a continuous water circulation through all the parts exposed to the heat. For the destruction of smoke and combustible gases there is in this example a complicated system of water tanks, baffle-walls and a water spray for the detention of dust. There are two fires for consuming the smoke and gases.

In all forms of crematories and incinerators their satisfactory working is dependent upon natural draft produced by high chimneys of steel or brick, since the temperatures of combustion are not sufficient to develop steam power for obtaining forced draft.

Two years ago the speaker had occasion to inquire into the number of municipal garbage cremating furnaces in use since 1885. It was found that some 160 patents had been taken out, under which about 188 furnaces and incinerators had been built for municipal purposes, besides some 20 plants for the disposal of refuse or rubbish only. It was also found that 108 of these municipal furnaces had been discontinued or abandoned for reasons of insanitary operation, large expense for repairs and maintenance, and inability to perform the stipulations of the contract. Since this inquiry was made, down to the present time, there have been installed in this country some eight furnaces of the older types, and two of a new form, differing widely from the others. During the same time about seven of the

older forms of crematories and incinerators have been permanently retired from use.

One of our foremost American engineers makes the following statement in regard to conditions of success in burning wet fuels:

> "The mass should be surrounded completely with highly heated surfaces in order that it may be rapidly dried, and the apparatus should be so arranged that the rapidity of combustion is precisely equal to, and never exceeds, the rapidity of dessication. When this rapidity of combustion is exceeded, the dry portion is rapidly consumed, leaving an uncovered mass of wet fuel which refuses to burn."

In other words, the material to be destroyed should be in contact with live fuel; it should be surrounded by highly heated radiating surfaces, and the ratio of combustion should correspond with the ratio of drying out.

Now, in a crematory or incinerator 35 to 40 ft. long, with fires at each end, and numerous doors, by the frequent opening of which the temperature is constantly lowered, the conditions described by Professor Thurston cannot be fulfilled.

In a crematory with a heavy primary fire at one end, with thick layers of wet material piled on transverse grates exposed only on the top to the flame, with doors admitting cold air at every two feet, the temperature might indeed be 1 500 or 1 800 degrees in the fire-box, but it would inevitably fall to 300 or 400 degrees before reaching the end of the chamber.

In one incinerator there are 38 doors and other openings for operating the machine. A volume of cold air is admitted through each opening, proportionate, of course, to its size. In this incinerator the grates are of pipe with water circulation, the temperature upon which, at 50 lb. steam pressure, would be about 280 degrees. At this temperature material placed on the grates simply stews; it does not burn. While at the fire 6 to 8 ft. below, the temperature may be at 1 500 degrees, at the point where the garbage is lying in contact with the grates it can hardly exceed 300 degrees fahr.

The destruction by fire of masses of garbage containing 65 to 75 per cent. of moisture means the breaking down of the tissues and the release of volumes of gaseous compounds. These are to be destroyed or transformed into CO_2 only at a continuous temperature of 1 500 degrees fahr. Once the gases are released by the primary fire, it is well-nigh impossible to retain them, or to reheat them to the point of ignition, unless by a special apparatus not a part of the crematory and incinerator construction.

The secondary fires employed on the exterior of the incinerators for the destruction of gases have proved inefficient. From an engineering standpoint this construction is a failure. The crematories and incinerators will burn material at low temperature, but it will not be destroyed in a proper way until radical changes have been made in the design of construction. This applies to the whole system of crematories and incinerators now used in American practice. We have built 200 and we have abandoned or destroyed one half of that number. To-day the whole crematory system is in process of being remodeled on the English destructor system of forced draft, and the end is not in sight. This means, gentlemen, that after twenty years of experiment the crematory system has proved unsatisfactory, and must give way to something better. We shouldn't go on repeating the mistakes of the past.

Disposal by Reduction Processes.

Before proceeding to the consideration of the reduction processes, it seems advisable to ascertain the relative composition and proportions of the ordinary American city waste.

Table I. Proportions of Municipal Waste.

Cities.	Ashes.	Garbage.	Refuse.
* Boston	87.20	10.43	2.28
† Greater New York	81.	12.	7.
† Manhattan and Bronx	82.04	8.30	9.66
† Richmond Borough	80.47	12.20	7.33
‡ Buffalo	55.3	7.	37.7
* Philadelphia	67.	28.	5.
† Washington	51.	36.	13.
* St. Louis	80.	13.	7.
‡ Milwaukee	53.7	24.5	21.8
† Montreal { Summer	10.	65.	25.
† Montreal { Winter	60.	25.	15.
General average	64.33	21.94	13.85

* Estimated in loads. † Estimated in tons. ‡ Estimated in cubic yards.

The classifications and subdivisions of waste in ten cities are here shown in Table I; but these figures must be taken as approximate only. It is difficult to get accurate information in regard to quantities and proportions, but in the main these are the amounts handled annually in each of the cities named, estimated in loads, tons and cubic yards. The reason for the radical difference observable in the Buffalo reports is the use of

natural gas as fuel and the consequent larger amount of refuse. In all the estimates made by the speaker the term *refuse* is used to designate the dry combustible rubbish, as distinguished from ashes and garbage. The climatic conditions in the various places are noticeable, as, for instance, in Montreal, where there is a wide difference between the composition of the summer and winter collections.

In Table II is shown quantities and proportions of municipal waste in New York City, including street sweepings.

TABLE II. CITY OF NEW YORK. QUANTITIES AND COMPOSITION WASTE.

Amount per Capita per Annum.	Lb.	Weights. Cu. Yd. per Load.	Weight per Load. Lb.	Weight per Yd. Lb.	Composition Average Samples. Moisture.	Carbon.	Ash.
Garbage.......	181	1.92	2 037	1 100	73.88	21.04	5.08
Ashes from dumps,	936	2.	2 172	1 086	32.42	26.23	41.35
From houses..	...	....	.....	.....	.66	22.35	76.99
Rubbish.......	93.	7.31	1 050	143	11.50	80.91	7.59
Street sweepings,	260	1.83	1 756	960	37.	31.	32.

The amount of waste annually removed from American cities is larger than is generally known. The annual per capita amount of waste in New York City, exclusive of street sweepings, is 1 210 lb. This amount is perhaps larger than that of any other city in the country, and it is owing to the fact that there are no facilities for destroying waste of any kind in the households or public buildings, except in a few instances. It has been estimated that if the total amount of waste annually produced in New York were heaped in one mass upon an area covering 22 548 sq. yd., the pile would be 1 112 ft. high, containing 3 159 182 tons.

TABLE III. AVERAGE PERCENTAGE COMPOSITION OF GARBAGE.

	New York. Waring. 1898.	Brooklyn. Taylor. 1896.	Dept. of Health. N. Y. 1897.	N. Y. City. Craven. 1899.	Philadelphia. Yarnel. 1907.	Jacksonville. Wiselogel, 1907.	New Bedford. Wheelwright. 1907.	Milwaukee. Sommer. 1907.	Cleveland. City Report. 1908.	England.	Berlin.
	1	2	3	4	5	6	7	8	9	10	11
Moisture......	71.	71.	70.	76.	71.	78.	81.	78.	83.4	65.	60.
Grease........	2.	2.	3.	3.	3.	3.4	3.3	1.9	3.3	2.	2.
Solids.........	20.	20.	20.	25.	20.	18.6	15.	20.1	13.3	24.	30.
Rubbish.......	7.	7.	7.	2.	6.	...	0.6	..	..	9.	8.

For the purpose of comparison Table III has been prepared, giving approximate percentage composition of garbage at various places. The first four examples vary but little and may be said to represent the average New York City garbage collection. Nos. 5, 6 and 7 are calculated from information contained in reports of the companies carrying on the work. No. 8 is calculated from laboratory analysis and No. 9 from the city report of operation of the municipal garbage plant for 1908. Nos. 10 and 11 are added for comparison of European conditions.

Some twenty-five years ago there was introduced into the United States a method of treating garbage for the recovery of the grease, and the manufacture of the residuum into a form of low-grade fertilizer. The first plant was built in Buffalo, in 1896, where a company was formed to manufacture grease and fertilizer from city refuse. The process as first practiced may be briefly described as a system of cooking for a period of from six to eight hours in cylindrical tanks under steam pressure, the garbage taken from the households of the city and as far as possible separated from ashes and rubbish and other foreign matter. During this cooking process the garbage is macerated and then discharged from the digester in the shape of pulp containing grease, water and oil from animal matter. The water is allowed to escape and the remainder is then treated with naphtha which dissolves the grease. The tankage remaining is subjected to a drying process by which the moisture is driven off, and when thoroughly dried is ground up as the base of a fertilizer. The separation of the grease and water is then completed and the naphtha recovered for subsequent use. The oil or grease obtained by the process is a dark, thick liquid containing many impurities, and a considerable percentage of naphtha, and is sent to market in this crude form.

The "Vienna" or "Merz" process, as introduced by the Buffalo Reduction Company, was subsequently adopted by several cities, and expensive works were erected upon the presumption that the results to be obtained in grease and tankage would justify the company in accepting a small payment from the city for its work. Plants were built under these patents in Chicago, Milwaukee, St. Louis, St. Paul and Denver, and some other cities. After unsuccessful experiment for several years all these plants, with two exceptions, were abandoned and closed for various reasons. A solvent process was first introduced at Providence by the Simonin Company and subsequently at Cincinnati and New Orleans, but after a few years of unsuccessful work was abandoned.

The plants now operating by the solvent or extractor process are very different from those first installed. They are successful in removing a larger proportion of the grease, and by better manufacture the tankage is made readily marketable. But it has been found that the plants are extremely liable to explosion and fires from the extra-hazardous risks necessary in work of this kind.

Shortly after the introduction of the reduction process in Buffalo a new method of treating garbage for the recovery of the oil was brought out in Boston. This was called the Arnold process, one of extraction of grease by steam only, recovery of grease being made by pressure, and the separation of the grease by flotation from the water. The first plant built in Boston was unsuccessful because of the nuisance created, and it was closed up by order of the board of health.

The second Arnold installation was made on a point of land extending into the harbor. After a short period of operation the plant was also removed on complaint of nuisance. The plant was reëstablished on Spectacle Island and has since been in continuous operation.

New Yoik City has had an Arnold reduction plant in operation since 1897, built on Barren Island, in New York Harbor. Garbage collected by the city carts is dumped into scows at the water front and towed about twenty-five miles down the harbor. By a system of conveyors it is taken to the top of the buildings, placed in a series of digesters and treated by heavy steam pressure for six hours. By heavy hydraulic pressure the grease and water are extracted, and by a system of drains are brought into a central reservoir where the grease rises to the top and is skimmed off into barrels. This method of hydraulic pressure has been improved upon by the use of a rotary press which receives material in a thin, uniform layer, and moves it on to the main platen below, passing between three sets of pressure rollers. The spring above provides for equal pressure, so that in case glass, or any other hard substance, enters the rotary the platen will not be broken.

The annoyance caused by reduction plants is largely caused by the odors driven off through the process of digestion. Heretofore it has been almost impossible to avoid these odors. But the adoption of this method of closing in the garbage press, and of pressing under cover and carrying the odors and gases through condensers and scrubbers, and through a gas-consuming chamber, does away with a large part of the odor nuisance. The Barren

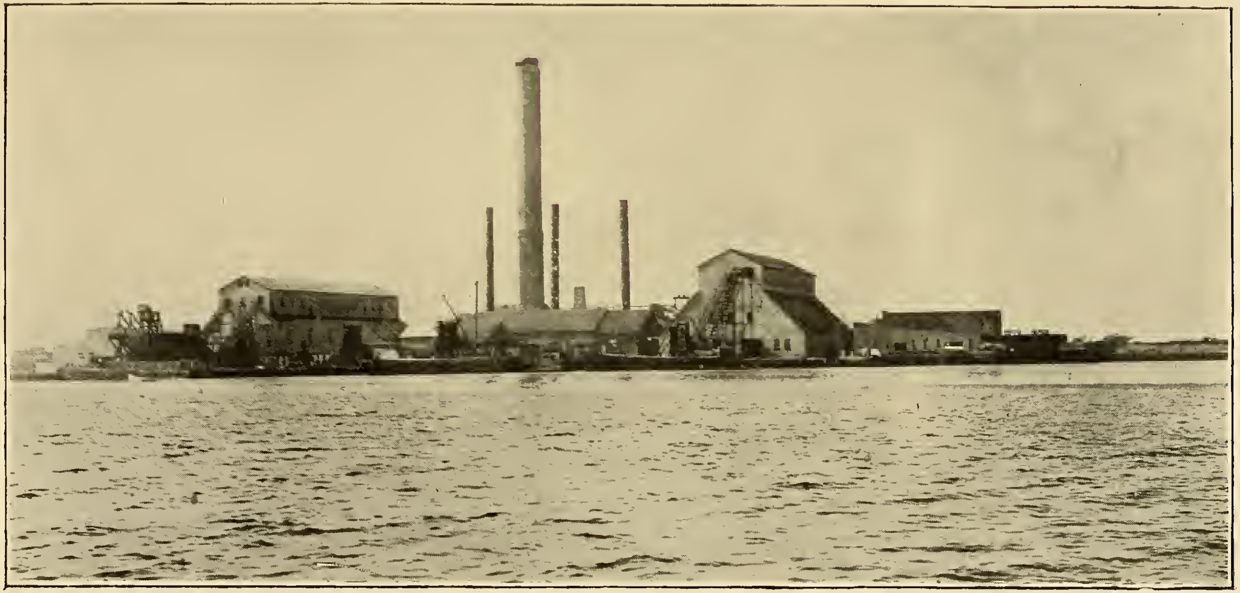

Fig. 2. Barren Island Reduction Plant, New York.

Island plant is the largest of its kind in the world. It is capable of handling 3 000 tons per day, being the daily amount collected in Manhattan, Brooklyn, Bronx and Queens boroughs during the summer season.

The franchise granted to the company has been renewed in five-year terms, and the increase in quantities has demanded the addition of new buildings and apparatus. Fig. 2 shows the extent of the buildings that are at present employed in this work. This plant has also frequently been the cause for complaint by holders of adjoining property. The odors and gas are a serious nuisance; until late years the plant has been frequently crippled by serious accidents impossible to avoid. The banks of the island have been worn away by the scour of the tide, causing the buildings to collapse, and disastrous fires occurred two years ago. This year the explosion of a digester injured the plant and caused loss of life.

Following the installation of the Arnold process in Boston, the municipalities of New York, Philadelphia, Newark and Baltimore adopted the same means of disposal of their garbage. Meanwhile, other companies employing somewhat similar means of treatment by the reduction process were organized in different parts of the country, and the work has been carried on with varying degrees of success in Detroit, Toledo, Cincinnati, Washington, St. Louis, New Orleans, Paterson, N. J., and some smaller cities.

Since the original construction there have been built, in all, some forty-five different plants, of which number more than one half have been abandoned, burned down or have passed out of use by other means. Nearly every one of the reduction plants in the United States has at some period of its operation been subjected to accidents, sometimes attended by loss of life. The exceptions to this are the later and more modern plants, built more carefully and with greater consideration of fire risks.

In all cases, with one exception, the reduction process has been the property of private companies which have received from the cities payment for the treatment of the garbage, and have retained as well the value of the marketable products of the plant. This has created a demand for the grease, which is used by foreign manufacturers, and for the tankage, which is used as a base for fertilizer in this country.

The business has been conducted entirely on a commercial basis. It has been impossible to obtain accurate and reliable information concerning the workings of plants, costs of main-

tenance and operation, etc. The cities have been forced to pay amounts varying from $0.50 to $2.65 per ton for reduction, and have also given franchises for terms of from five to ten years, because of the supposedly excessive cost of construction and operation of the works. The competition in the construction of plants has been limited to two or three builders. It has been carefully given out, and is generally believed that no city of less than 100 000 population can afford to install a garbage reduction plant because of the large sum required for construction. It was also advanced by the reduction companies that this process was absolutely the only sanitary method of garbage disposal; the only one safe from the danger of infection and contagion.

These conditions prevailed up to about five years ago, at which time the city of Cleveland bought outright a reduction plant, and with the aid of experts so changed and improved the system that it has been proved possible to conduct it at a profit to the city. The works are located some seven miles outside of Cleveland, on a line of railway, and the garbage is conveyed on this line in a special form of car. The method employed is a combination of the solvent and of the digester processes. The cuts herewith show the exterior of the buildings, and the special form of car used for conveying the garbage; the digesters in which the garbage is treated by steam and the percolators where the naphtha process is introduced for the purpose of removing the grease and oil. The results of this work may be briefly stated as follows:

The official public reports made by the city of Cleveland show that in five years' operation of a municipal reduction plant, with an expenditure the first year of $80 000, and at the end of five years a total expenditure of $225 000 for the buildings and machinery, surprising results have been attained. The city began with a revenue of about 7 per cent. upon its investment, which represented a profit of 16 cents per ton. The next year it was 14 per cent., and the year following it was 22 per cent., which means about $1.46 per ton. So it continued until 1909, when the actual revenue from tankage, grease and other salable materials is said to have amounted to $100 000. Under ordinary conditions, with a total garbage collection of not more than 45 000 tons a year, this would represent 40 per cent. upon the present valuation of the investment. At the present time the reports from the city of Cleveland show that the net profit per ton which may be recovered from ordinary garbage is about $3.46. Apparently the possibilities of profit in the garbage reduction trade are very great.

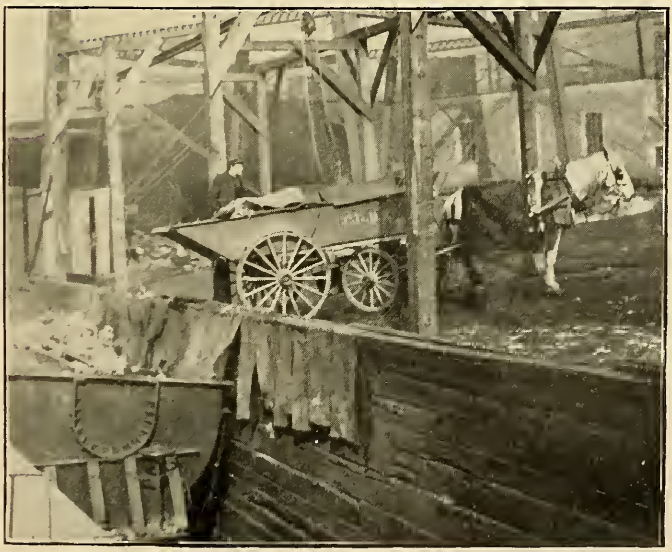

Fig. 1. Improved Collection-Can Wagon, Boston.
Fig. 4. General View, Cleveland Plant.
Fig. 3. Garbage Cart and Railway Car, Cleveland Plant.

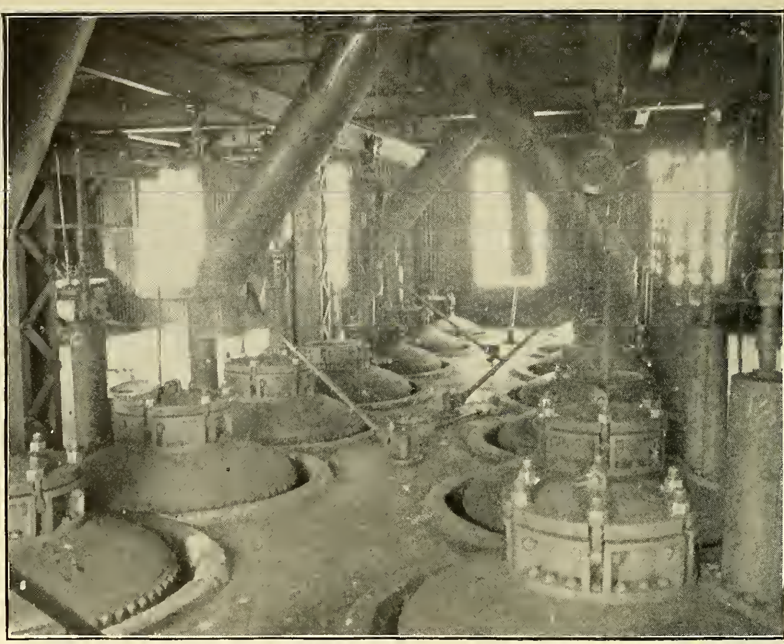

FIG. 5. DIGESTERS, CLEVELAND PLANT.

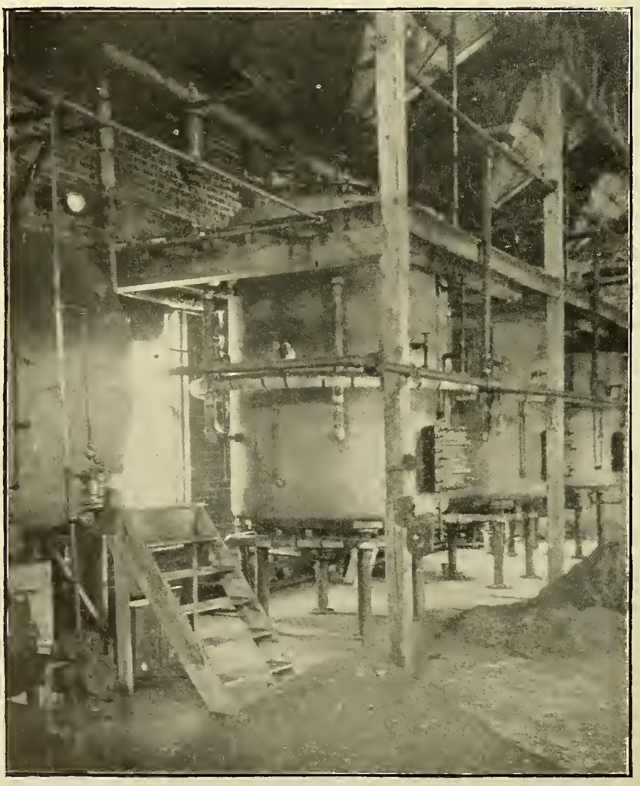

FIG. 6. PERCOLATORS, CLEVELAND PLANT.

The example of Cleveland has been followed at Columbus, Ohio, where a municipal garbage reduction plant built and operated by the city has just gone into service. The garbage is collected in steel wagons, discharged at a central loading station into steel cars drawn over the city's own railroad to the works located next to the sewage disposal station, 1½ miles south of the city limits. The cars are run into a building and dumped on a concrete floor where a separation is made of the cans, bottles, rags, etc. A conveyor takes the garbage to an adjoining building containing six digesters, and steam is turned on for sufficient time to macerate the material and separate the grease, which rises to the top of the digester and is removed to tanks for further separation and purifying for market. The water is reduced by evaporation to a thick consistency called "stick" which contains the fertilizing properties, and is afterwards mixed with the tankage. The solid portion from the digesters is passed through a roller press which removes the water, and being mixed with the "stick," is then ready for sale.

The operation is almost wholly automatic, only hand labor being used at the beginning to remove the rubbish and for shoveling the garbage into the conveyor, and later handling the tankage at the mixing tank. With these two exceptions this is a closed process, the garbage being exposed to the air only during the stage of conveying from the dumping house to the digesters and later from the roller presses to the mixing tank. This reduces the danger of nuisance from the escape of odors, but does not altogether avoid the chance of odors being created within the building. This plant is said to have cost for the building $100 000, and for the complete equipment of machinery $150 000 more. The capacity of this plant is 80 tons per day, though at present about 60 tons are treated. It is anticipated that the revenue will approach if not equal that derived from the Cleveland works in proportion to the quantity treated. If this be the case there is no reason why other cities should not follow the example of Cleveland and Columbus, and enjoy the profits arising from the reduction service.

There are many things to be considered in this connection, of course. There is the question of the advisability of the expenditure of a considerable amount of money in a business which is at best an extra-hazardous one. There might be some question as to the market returns from grease and oil and tankage later on, when the supply may more than equal the demand. Moreover, it requires a very high degree of technical skill and

executive capacity to construct and operate a garbage reduction plant in a satisfactory manner. But we must acknowledge that the revenue to be derived from a ton of ordinary garbage is very considerable, and it is an open question whether a city should not profit by the experience of others and reduce this garbage by its own agency.

The garbage contract of the city of Boston expires in a year or so, and the suggestion may be made as to whether it would not be satisfactory and sanitary for the city to establish a garbage disposal plant and enjoy the revenue therefrom, or whether it shall ask the garbage company to consider the real value of their manufactured products and so reduce their prices that the city may participate in the profits of the work. Surely it is obvious that the reduction companies should consider the value of the manufactured product and be satisfied with a reasonable profit, and let the city have a part of the advantage.

There are many difficulties connected with that question which do not now enter into its engineering side. In all the twenty years that this work has been going on it has been slowly developed by companies which have invested their capital, trained their own management, established their own engineering facilities, and thereby developed a special class of engineers; it has resulted in the development of a system of reduction that American municipalities can easily avail themselves of now, and may do so without the opposition of the companies. Any city may build its own plant, run it and make a profit out of it.

As before stated, the great difficulty arising from the operation of a reduction plant has been the nuisance of odors produced at one or another stage of the process. By a system of fans and scrubbers, and a method of destroying the odors by high temperature, some plants have succeeded in abating this nuisance in a large degree. Two new methods of reduction have lately been presented, one of them consisting mainly in the introduction of methods which carry on the treatment continuously in closed steam receptacles. One of these plants was invented by Mr. F. Wiselogel, and is at present in the hands of the United States Construction and Utilization Company, of Rochester, N. Y. By this process the garbage is not released until the completion of the extraction of grease and oil; the tankage is dried by rotary presses, the residuum being taken out in shape for market as a fertilizer base.

The plant at Vincennes, Ind., which was constructed under this method, after several years' operation was destroyed by

fire and a new plant has taken its place. The constructors are to install a similar plant at East St. Louis.

It has been found perfectly possible to treat garbage in small amounts of 5 to 25 tons by this method, thus bringing the process within reach of the smaller cities. This Wiselogel method is the result of many years of experiment on the part of the inventor.

Another process of a somewhat similar character has been in use in New Bedford. This is called the "Wheelwright hot-water extraction process," managed by the International Continuous Filter Press Company, of Providence. In this method also there is no release of the material until the process is complete. This New Bedford plant was constructed two or three years ago, under a ten years' contract with the city. At present it is not operated to more than half of its capacity. It costs the city of New Bedford $4.16 per ton to collect and dispose of the garbage. If we assume that it costs $2 a ton to collect the garbage, then it costs $2.16 a ton to dispose of it. There is no doubt that the work is well done — but it is too costly.

It is understood that the city of Bridgeport has also adopted the Wheelwright process, and is about to install a plant for the treatment of from 20 to 30 tons of garbage per day.

The treatment of garbage by reduction for the recovery of the marketable portions is a practice peculiar to America, not in force in other countries. It has been brought to its present profitable stage by private companies, which are ready to contract for the erection of plants on a basis of payment by the city of a fixed sum per ton of garbage delivered, for a period of five or ten years.

There are other companies that manufacture the machinery necessary to equip a reduction plant, but do not themselves engage in reduction work. By their aid any town may install a complete reduction plant and operate this for the advantage and benefit of the community.

It is evident that this method of disposal of a part of the waste has become firmly established as a part of the American system, and must be taken into account by all communities when considering modern means of municipal waste disposal.

The Disposal of Waste by the Destructor System.

When municipal waste in an unsorted or mixed condition is to be destroyed by fire, it becomes necessary to know the composition and calorific value of the several constituents. The following tables give results of analysis at various places.

Table IV. Analysis New York City Waste.

Calorimeter Tests and Proximate Analysis of Samples collected in Four Seasons of Year 1907.

	Moisture.	Volatile Matter.	Carbon.	Ash.
Garbage, 25 tests	73.26	16.89	4.71	5.14
Coal and cinders, 26 tests	1.34	3.73	55.00	39.93
Fine ash screened from collections	1.20	4.02	17.38	77.40
Rubbish, 26 tests	5.78	65.66	14.69	13.87

This laboratory analysis, made by Mr. B. F. Welton (reported Proc. Am. Soc. C. E., Vol. XXXIII, No. 9) from samples taken over a period of one year, was made to obtain data from which could be determined the feasibility of disposal of the wastes of Richmond Borough by self-combustion in a refuse destructor of the same general type as used in Great Britain. Taken in conjunction with a series of practical tests in burning mixed waste made by Mr. J. T. Fetherston, the results of the laboratory determinations, the practical trials, and an examination of some forty different destructors in Great Britain, the final outcome was the construction of the disposal plant at New Brighton, Staten Island, in 1908.

Table V. Chemical Analysis of New York City Waste.

Chemical Analyses of Dry Composite Samples of Coal and Cinders, Garbage, and Rubbish, 1905–06.

Constituents.	Coal and Cinders. Per Cent.	Garbage. Per Cent.	Rubbish. Per Cent.
Carbon	55.77	43.10	42.39
Hydrogen	0.75	6.24	5.96
Nitrogen	0.64	3.70	3.41
Oxygen	2.37	27.74	33.52
Silica	30.01	7.56	6.49
Iron oxide and alumina	8.98	0.41	2.03
Lime	1.21	4.26	2.26
Magnesia	Trace	0.28	0.57
Phosphoric acid	None	1.47	0.10
Carbonic acid	None	0.59	1.49
Lead	Trace	0.20	0.52
Tin	Trace sulphides		Trace
Alkalies and undetermined	0.27	4.45	1.21
Calorific Values in British Thermal Units.			
Calculated from above analyses	8 382	7 970	7 250
Average of calorimeter determinations	8 510	8 351	7 251

In Table V the examination of New York waste is carried one step further by the chemical analysis of dry samples to determine the exact constituents and the approximate calorific values.

TABLE VI. CITY OF BOSTON, STREET DEPARTMENT, SANITARY DIVISION.

Results of Mechanical Separation of Mixed Refuse collected December 2, 1909, to January 14, 1910.

23 loads — Representative City Districts — 54 810 lb.

	Pounds.	Per Cent.
Combustible:		
* Unconsumed coal	18 213	33.23
Paper and rags	7 309	13.33
Garbage	4 054	7.40
Wood	142	.26
Shoes	48	.09
Hay and straw	80	.14
Total	29 846	54.45
Non-combustible:		
Ashes and clinker	23 392	42.68
Tins and iron	838	1.53
Crockery and glass	734	1.34
Total	24 964	45.55

* Contains not exceeding 1 per cent. of fine garbage.

Table VI condensed from a report made by the Sanitary Division of the city of Boston is added to show the relative proportions of combustible and non-combustible matter contained in the mixed collection of the city waste as indicated in these representative districts.

TABLE VII. ANALYSIS OF MUNICIPAL WASTE, MILWAUKEE (S. A. GREELEY).

Average of Five Laboratory Tests. Percentage Proportions by Weight.

	Moisture.	Carbon.	Volatile Matter.	Ash.
Garbage	70.6	4.1	17.6	7.7
Ashes	18.0	23.3	5.8	52.9
Rubbish	24.9	14.9	36.3	23.9
Manure	53.1	10.1	28.9	7.9
Street sweepings	33.5	9.31	14.6	43.04

From samples taken from city carts during the trials of the Milwaukee refuse incinerator, May 18 to June 1, 1910.

Table VII contains the analysis of mixed waste made from samples taken from the city collection wagons, Milwaukee, at the time of the trials for the acceptance of the refuse incinerator by the city. The figures given are the average of five separate tests made from each constituent. Street sweepings were not a part of this trial, but the analysis is added for information and comparison with other places.

In all these tables there are but few points where the figures can be compared on a basis common to all. But few accurate analyses have been made, and these are not based on a method

which is accepted as representative standard for all analyses. Tables IV and VII, computed from the same data, but for different periods of the year, and dealing with different proportions of the waste, furnish the best details for comparison. What is needed in this work is a standard method of analysis which shall give the determinations in a form that can be readily used for comparison at other places.

The necessity for preliminary study of waste conditions preparatory to the adoption of the modern waste disposal methods is now generally recognized by all the authorities. When these studies are made by competent engineers on a basis common to all, the advance in improved means of caring for municipal waste will be greatly aided.

The British Destructor System.

The destruction of "towns' refuse" — the English term for municipal waste — began in London about 1870, by the Messrs. Mead, dust contractors at Paddington, who built the first closed furnaces for disposal of refuse. Because of defects in construction, these were unsuccessful and were discontinued. The idea was taken up by others, and in 1876 the first destructor was built by Mr. Alfred Fryer at Manchester. This term "destructor" has come generally into use as describing the several forms of English apparatus used for incineration of refuse. The two original cells which gave life to the whole destructor principle are still in use at Manchester.

Mr. Fryer's destructor was of the "cell" type; an oven floored with inclined fire grates, fed through top charging ports, the gases of the combustion passing through side ports to a main flue connected with the chimney. The cells were built in pairs, placed back to back, arranged in rows, all being connected with the main flue. The operation was by natural chimney draft, very high stacks being required to obtain the necessary power. Since the combustion in these early plants was slow and imperfect, it was found necessary to introduce a fume-cremator in the path of the gases, and later a horizontal steam boiler was placed in the main flue to obtain power.

In 1885 the fan was first used for forced draft, an improvement that had far-reaching effect. In 1887, the Horsfall destructor embodied a number of improvements, including the water-tube steam boiler, the exhaust fan and the use of a steam jet blower for the distribution of air through heavy boxes of cast iron, placed at the sides of the fire bars.

The Fryer destructor was improved and changed by the makers, Messrs. Manlove Alliott & Co., and has kept its position in the foremost line of progress. The Warner "Perfectus" destructor, also of the cell type, has several installations in England.

In 1891, there were some 200 cells at work, destroying 500 000 tons of refuse annually. The Beaman and Deas Cell Destructor appeared in 1893 with other improvements, raising the capacity of the cells to 15 to 20 tons each per day, and developing greater steam power.

The first radical departure from the cell type was made by the Meldrum destructor in 1894. This was the Meldrum continuous grate, with divided ash-pits, and included the regenerative air-heating system for supplying the air for combustion at high temperature by means of steam jets under the fire bars. The introduction of a powerful blast of air heated to 350 degrees fahr. under each separate grate greatly increased the rate of combustion and preserved the principle of alternate charging of one section or grate, while the adjoining sections were at the highest temperature. The enlargement of the combustion chamber provided for the maintenance of the temperature at a nearly uniform rate, and the complete combustion of the gases before their entrance to the boiler. There was also provision made for the settlement and detention of the fire dust, in the bottom of the combustion chamber and below the regenerator, in a special dust-collecting chamber. With the aid of these improvements the Meldrum Simplex Destructor obtained a commanding position, installing in the first sixteen years of its work upwards of 110 plants, of which some 90 were in Great Britain and Ireland, the others being distributed in various parts of the world.

The Heenan Destructor was evolved from furnaces patented in 1897 and 1901, and assumed nearly its present form in 1902 when built at Barrow, England. As at present constructed, the Heenan Destructor has the continuous grates with closed ash-pits, the air regenerative system with the delivery of the heated air beneath the grates by a fan or blower instead of steam jets. The roof of the furnace is undulating, comprising a series of shallow reverberatory arches over each grate, the purpose being to create eddies or currents of hot air deflected upon the adjoining grates. The air supplied for combustion is heated by the regenerator to about 350 degrees fahr. and delivered under the ash-pits, at a pressure of 2 to 3 inches water gage, by a powerful fan

driven by steam engine or electric motors. The ventilating systems of air ducts from all parts of the building are connected with the intake of the fan, insuring the removal of dust and preventing its escape to the outside of the works. The clinker removed through the front doors of the furnace is dropped to a lower level below the clinkering floor, where it is held in cooling chambers until nearly all the heat contained in the clinker has been returned to the furnace.

In the latest example there is a supplemental hot-gas duct by which the hot gases from the clinker chambers are passed by means of steam jets through the back wall of the furnace. The purpose of this is to partly dry out the moisture from the refuse as it stands on the back hearth before it is raked over on the fires.

Since its construction in nearly its present form in 1902, the Heenan Destructor has undergone many changes, the improvements being for obtaining a higher rate of combustion, greater development of steam power, the more economical operation with less exposure of the workmen to the high temperatures in operating the furnaces, and the cooling and more perfect ventilation of all parts of the enclosing building. There have been built, or are now under construction, sixty destructors of the Heenan type since 1902.

The English Destructors in America.

The first installation of the British cell destructor on this continent was at Montreal in 1894, when one closely following the original Fryer model went into service, and is still in use. This was followed by a large plant of the same type at San Francisco, but no other installations for municipal service were made.

It was not until 1906 that the first destructor of the modern high-temperature steam-raising form was built by Meldrum Brothers at Westmount, a suburb of Montreal. The published reports of the trials for the acceptance of this destructor made in 1906 showed conclusively that the destructor system could be applied under American conditions and obtain very nearly the same results as in the British installations. The trials showed that from 30 to 50 tons of mixed waste, garbage, ashes and refuse could be consumed without additional fuel, developing 200 h.p. of steam at 125 lb. pressure, with an average temperature of 1 900 degrees fahr. in the combustion chamber, at a cost of 80 cents per ton including all labor for operation, fixed charges

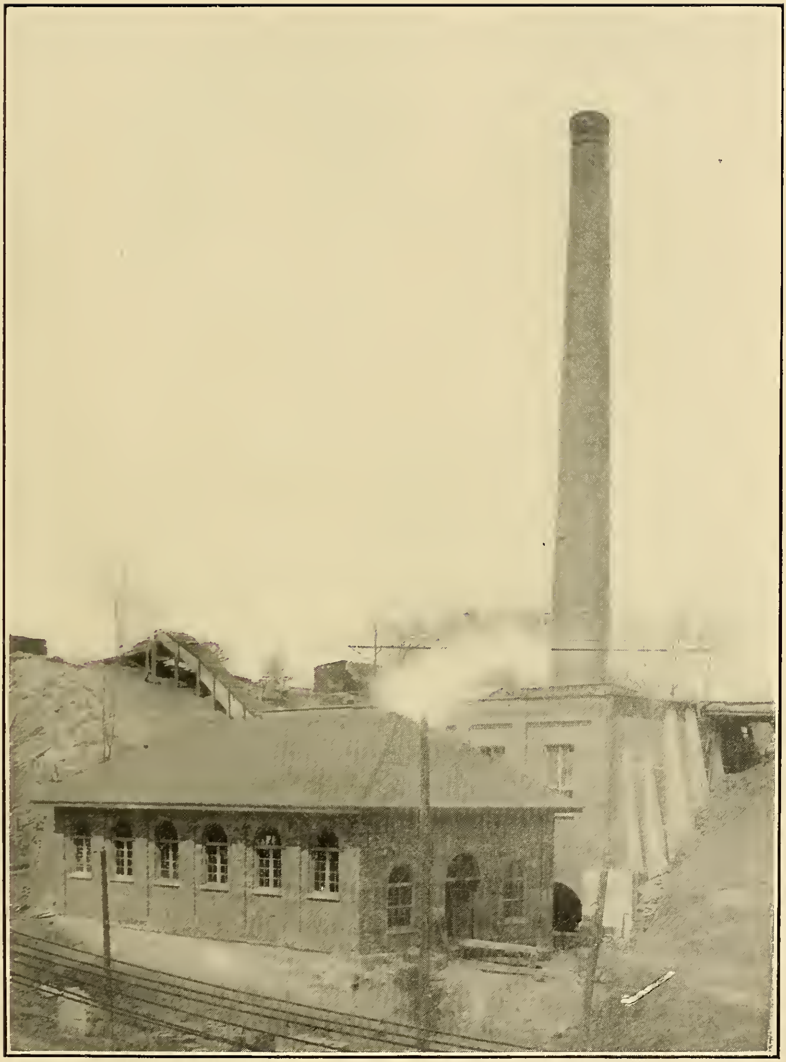

Fig. 7. Meldrum Destructor, Westmount.

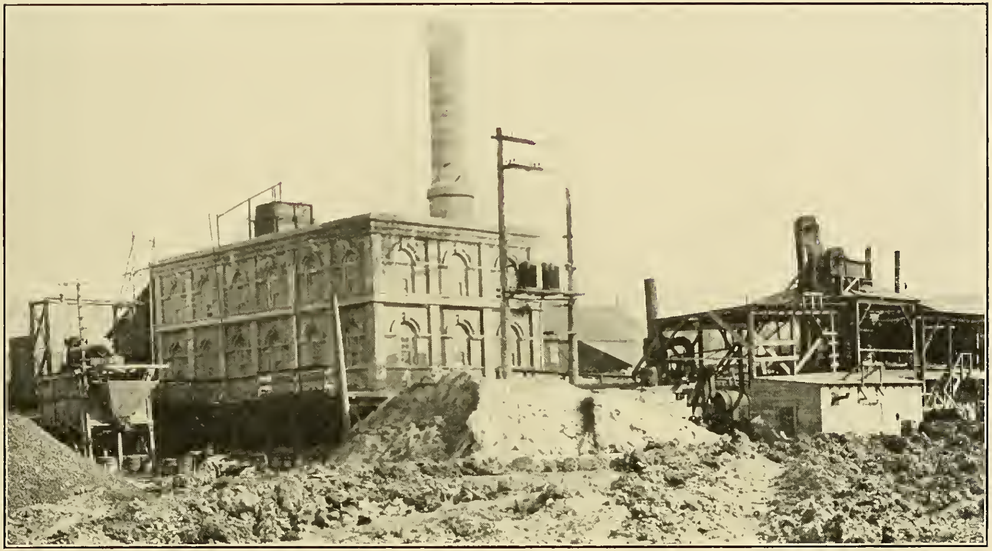

Fig. 9. Seattle Destructor House built with concrete blocks made from clinker from Destructor.

and sinking fund. The net cost for labor was 31 cents per ton, and the revenue in steam power delivered to the electric lighting stations was approximately $5 000 per year. The continuous operation of this plant for four years has been so successful that another destructor of the same capacity has been installed.

Following the example of Westmount, another Canadian city, Vancouver, obtained tenders for a destructor plant of 40 tons daily capacity. This contract was awarded to Messrs. Heenan & Froude, of Manchester, England, the destructor going into service in January, 1907. The reports of May, 1909, showed the disposal of the maximum quantity of waste of low calorific value at a cost of 91 cents per ton, including all operating costs and fixed charges and a net cost of 46 cents per ton after deducting revenue. This city has since contracted for another destructor plant of 140 tons capacity, the steam power from this to be used in several departments of municipal work.

The success of these Canadian installations led to a more thorough examination of the value of destructor methods for American towns, and in 1907 a destructor of the Meldrum type was installed at Seattle, Wash., by Mr. R. H. Thompson, city engineer. This was the first English destructor built in the United States, and included some special features which have since been adopted in other installations. It is reported that the city will shortly install two other plants of the Meldrum type for disposal of all the waste. The table following gives a condensed report of the operation of this destructor for the years 1908–09.

TABLE VIII. REPORT SEATTLE DESTRUCTOR.

Destructor Meldrum, 1 Unit, 4 Cells, Front Feed. Rated Capacity, 67 Tons Mixed Refuse in Twenty-four Hours.

	10 Months, 1908. Feb. to Dec.	12 Months, 1908–09. Dec. to Dec.
Total tons burned	16 340.6	23 111.8
Total tons burned per month	1 634.0	1 925.1
Total tons burned per day	63.	74.
Composition:		
Ashes, per cent. of whole quantity	40.2	44.2
Manure, per cent. of whole quantity	14.1	2.7
Garbage, per cent of whole quantity	23.4	33.9
Rubbish, per cent. of whole quantity	21.5	19.5
Average cost per ton	$0.79	$0.748
Returns from clinker and power		0.2715
Net cost per ton	$0.79	$0.4765
Average evaporation per lb. of refuse	1 lb.	0.90 lb.

Equipment:
 1 B. & W. boiler, 2 201 sq. ft. surface.
 1 250 kw. generator.
Power used for:
 1 pump (1 000 000 gallons) for fire protection.
 1 crusher and screens for clinker.
Collection: By licensed garbage men entirely under private control.

The value of residuals from a destructor is well shown by the use made of the clinker in Seattle. When the destructor was first built, it was inclosed in a wooden house of light construction. This has now been replaced by a structure of concrete blocks made from the clinker accumulated in the year's work. Many buildings have been built abroad from clinker concrete, but this is the first instance of its utilization for this purpose in this country.

The destructor at New Brighton (borough of Richmond and New York City) was the outcome of an extended survey of many British destructors abroad, and a thorough study of local conditions made by Mr. J. T. Fetherston, superintendent of street cleaning, Borough of Richmond, in 1906–07. The tenders of Messrs. Heenan & Froude, of Manchester, England, were accepted for a four-grate Heenan destructor with a capacity of 60 tons per day, to develop 200 h.p. of steam, to operate without nuisance and to destroy the unseparated waste without other fuel. This plant being easily accessible from all parts of this country has received more attention than any other American destructor and has been frequently described and illustrated by the engineering papers. At present the capacity of the plant has not been fully reached, as the average quantities are about 30 tons per day. The evaporation of water per pound of waste consumed at the tests made in 1908 was 1.3 lb. per lb. of refuse. There is no present use for the steam power, though it will be utilized in the near future. Because of no revenue from the power, the operating costs are large, being reported in 1909 at $1.28 per ton of refuse consumed. The electric generating plant now being installed will presently afford power for lighting some of the city's stables, and for running the city construction and repair shops. The borough has made plans for the erection of a large destructor plant at Clifton, with a capacity of 90 tons, and another at Tottenville, the extreme southern point of the island, with a capacity of 20 tons. The plans include the erection of new stables for the Street Cleaning Department, cottage and buildings for the superintendents of the various departments of street service and the destructor work.

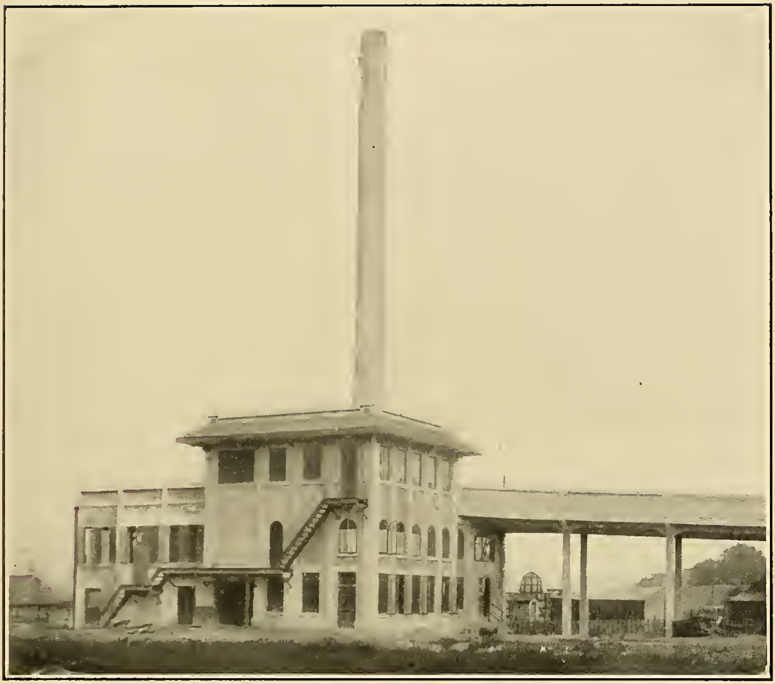

Fig. 10. Heenan Destructor Plant, New Brighton, N. Y.

Fig. 11. Meldrum Destructor at General Electric Company, Schenectady, N. Y.

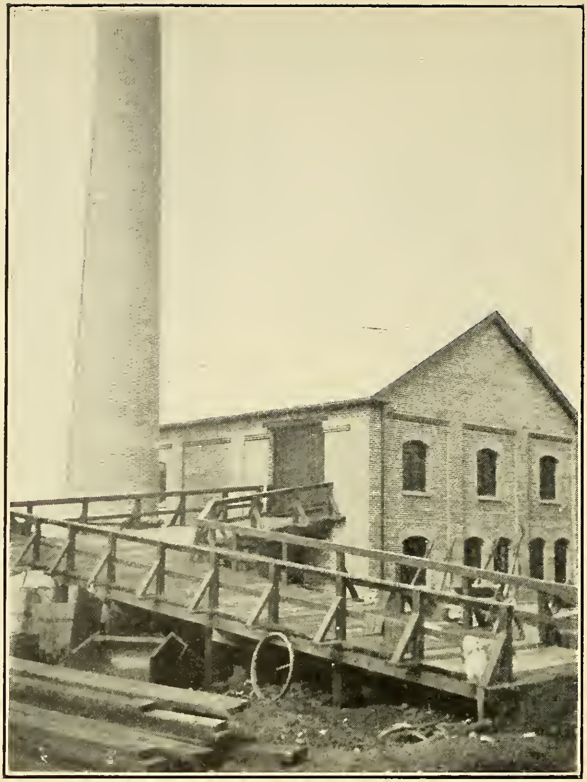

Fig. 8. General View Heenan Destructor, Vancouver.

Fig. 12. General View Heenan Destructor, Milwaukee.

The adaptation of the destructor method for the disposal of waste from industrial establishments is illustrated by the work of a Meldrum destructor built for the General Electric Company at Schenectady, N. Y., in 1908. This plant of two grates was specially designed for the combustion of 25 tons per day of combustibles, paper, wood, shavings, sawdust and a large amount of box material, barrels, etc., which could not be utilized. There is a 250 h.p. water-tube boiler which is in connection with the main steam line of the works. The great heat from the combustion of this dry material compels an overload of 25 to 33 per cent. to be carried by the boiler, the temperatures of the combustion chamber ranging from 1 900 to 2 800 degrees fahr. No complete series of tests have been made, but the preliminary trials showed an evaporation of 2 to 3.5 lb. of water per lb. of waste consumed. The clinker is very heavy because of the presence of large amounts of iron in the waste. The operation demonstrates that industrial waste of a great manufacturing plant can be converted into power with a moderate cost for initial plant, and the certainty of obtaining a revenue in steam that will more than repay the costs for operating and the fixed charges on construction.

A Heenan destructor has been installed at Buffalo at the refuse utilization station, owned and operated by the city in conjunction with the sewage pumping station. This destructor will be operated by the rejected parts of the light refuse that are left after the salable percentages are sorted out and sent to market. The steam power from the destructor will be employed in the sewage pumping station adjoining the destructor building, saving the fuel and labor heretofore necessary for the boiler plant of the sewage works.

The city of Montgomery has contracted for the erection of a refuse disposal plant which will include a reinforced concrete building, radial brick stack, and four-grate Heenan destructor with 200 h.p. boiler. The steam power from this station will be utilized in the operation of the municipal water pumping station.

The latest installation of the destructor system is at Milwaukee, where a large plant having a capacity of 300 tons per day has just gone into service. Milwaukee in past years has had an extended and unfortunate experience with various means of waste disposal, having had three crematories, two reduction processes and the usual unhappy dumping in water and on land. The destructor now installed replaces the larger cremator of the Engle type built in 1901, with a rated capacity of 120 tons. This crematory was unfortunately located, involving large ex-

pense for transportation of the garbage; repairs and the operating costs were excessive. The JOURNAL of this society for November, 1909, contained a paper by Mr. S. A. Greeley, resident engineer, which fully described the preliminary studies of the waste, the plans and specifications for the proposed plant and the expected results to be obtained. The details of construction, destructor and machinery equipment, and report of the trials made for acceptance of the plant in May of this year, have been fully described in the engineering journals of late issues.

In designing the plant, Messrs. Hering and Fuller, the consulting engineers in charge, introduced many new features, chiefly those connected with the reception and handling of the waste; the removal of free water by drains in the floor of the storage hoppers; a complete system of ventilating air ducts from all parts of the building; the separation of the charging, firing and clinking work from the machinery rooms; the conveying of clinker from the building; and the arrangement of the electric generators and other machinery in the most compact form, with utmost economy of room. There has probably never been built a disposal plant of the same capacity that occupies so little ground, nor one where the operation of the works is done with so small percentage of hand labor.

The destructors are of the Heenan type, built in 4 units of 6 grates each, with four 200-h.p. water-tube boilers connected with a central main flue leading to the chimney of radial brick 154 ft. high and 10 ft. interior diameter. The furnaces are top fed, through containers or charging hoppers holding 1 cu. yd., operated by the fireman from the floor in front of the furnace. The clinker is withdrawn through the front doors in the furnace and falls through trap doors into clinker cars on the basement floor. The cost of this plant for foundations and framework of buildings, the destructors, boilers and machinery equipment under the contract of the Power Specialty Company, of New York, was $175 000. The building and appurtenances were $20 000; the chimney, $4 500; the engineering and inspection fees, $5 000; and extras, $4 485; making, in round numbers, $208 985 as the total cost exclusive of the ground. The tests for acceptance of the plant were made under three conditions of extreme summer refuse, extreme winter refuse, and average annual refuse. Table VII gives the average analysis of the waste as burned under these conditions. The results of these tests showed that about 10 per cent. more refuse was destroyed than was called for in the contract; that the steam requirements

were exceeded by about 30 per cent. and that the operating costs were from 20 to 25 per cent. less than the conditions of the contract. All other points of contract conditions, the average temperature maintained, the combustion of 60 lb. of waste per square foot of grate per hour; the residual thoroughly burned and free from organic matter, and no nuisance from dust or odors created during the operation, were completely fulfilled.

TABLE IX. TEST COST OF OPERATION OF MILWAUKEE REFUSE INCINERATOR. AVERAGE ANNUAL REFUSE.

Tons incinerated during test		126.81
Labor required:		
One feeder, 37 hr. at 25 cts.	$9.25	
Three firemen, 37 hr. at 25 cts.	27.75	
¼ engineer's time, 37 hr. at 37½ cts.	3.47	
Total cost		$40.47
Cost of labor per ton		31.9 cts.
Steam from and at 212 degrees fahr. to operate fan engine and feed pump per ton		219 lb.
Cost of steam used per ton, at 4 cts. per 100 lb.		8.8 cts.
Total cost to incinerate one ton		40.7 cts.
Total steam generated from and at 212 degrees fahr. per ton		2 680 lb.
Value of steam per ton of refuse burned at 4 cts. per 100 lb.		107.2 cts.
Net profit per ton of refuse burned		66.5 cts.

At the present time there is no opportunity to use the steam power or utilize the large amounts of clinker produced. Undoubtedly in the near future a way will be found by means of which the revenue from these items will be placed as it belongs, to the credit of the destructor. The results obtained compare favorably with those reported from the destructors operating in Great Britain, and as the plant continues in use and the men become more expert in its management, there will be a decrease in the net operating expenses.

The city of Portland, Ore., after some four years of effort to obtain satisfactory tenders, has accepted the proposals of a local construction company for the installation of a large disposal station with a capacity of 150 tons per day. The designs for this plant, made by the Public Works Engineering Company, follow the construction of the English continuous-cell destructors in all important details, with some additions and modifications intended to give a larger capacity, greater steam development, with no more initial cost for the plant. It is understood that this installation has been completed and is about to go into service.

The review of the work of destructors and their coming installation in this country indicates a strong movement toward

the establishment of disposal stations that will utilize all waste products of the community. It was about twenty years ago that Lord Kelvin pointed out the possibility of converting waste material into electrical energy, by which means each inhabitant might be furnished with an 8 c.p. electric light during the time this was needed for illumination. This was thought to be a fanciful and imaginative supposition, but succeeding years have shown that it is not altogether an impossibility. Whether a part of the waste be utilized by one or another form of reduction process, or by the combustion of all and the employment of steam power and the residuals, it is now a demonstrated and practical thing, and there is no more useful way of turning into the pockets of the taxpayers the values of the municipal waste now thrown away.

This question of the treatment and disposal of the city's waste is a matter of great moment to the people of this city of Boston. This society should, as engineers, indicate that a reasonable progress will be expected and required from the authorities. It is an engineering question, and must be dealt with as such. The sanitary question is of course the leading factor, since it concerns the health and comfort of the people, but sanitary measures are best carried to practical service by trained engineers whose skill, knowledge and experience are indispensable to achieve the desired results.

DISCUSSION.

A Member. — I'd like to ask Colonel Morse what becomes of the clinker from an incinerator plant. In some places, I understood, it is utilized. But is the character of it such that in plants in America it is entirely inoffensive?

Mr. Morse. — I neglected to say that I had several analyses made, and I find the proportions to be: Silica, 40, 60 to 65 per cent.; lime, from 7 to perhaps 15 per cent.; and of compounds of iron, oxides and similar compounds, somewhere about 8 or 9 per cent., and of magnesia, 7 or 8 per cent. Roughly speaking, those are the constituent parts. When it comes from a destructor, this is a very hard material that comes out in chunks. I have seen 30 to 40 tons taken out in the same condition. At that time, it has a high temperature, — 1 200 to 1 500 degrees and upwards, — but the temperature rapidly falls on exposure to the air. In volume it is much larger in its new condition than it was before. Then, after it has been allowed to stand and disintegrate, it is broken up and ground up into any size

desired, so that you may be able to get clinker of any shape to use for concrete. In Westmount, they first tried this experiment. At first they gave it away. Now they have a demand for it for one purpose or another. It is probably not advisable to use it in all classes of concrete work, but it is possible. Also it ought not to be in contact with any iron work, because there may be more or less sulphur, which attacks the iron. But for all purposes of sidewalks and bottom fillings for roads, or wherever there is use for a rough character of stone, it is eminently suitable and useful. They are carrying on a series of experiments at New Brighton for the purpose of determining what can be done with clinker — grinding it up and making brick and cement from the clinker itself. I saw a briquette set in a day, while it ordinarily requires from seven to eight days for a cement briquette to set. And it is stronger than the cement itself. There is a certain composition which will make a stronger setting than any composition of sand and stone of which we now know. In other words, the crushing strength is greater than that of the ordinary briquette. I believe this is to be possible, that 20 or 30 per cent. of the total weight of residuals from all destructor plants will be useful for all sorts of municipal rough work, and would represent, roughly speaking, at least 50 cents per ton. So there is an asset to the credit of the clinker that should be taken into account. With the experiments going on here and in Europe — for this same process is being carried on by a number of countries — I believe that we shall arrive at a point where every particle of clinker will find a useful purpose, and not only pay for itself, but provide a revenue. At the present time it can only be said that for all rough work it is eminently useful and finds a satisfactory market.

MEMBER. — I should like to ask Mr. Morse if he has any knowledge of the cost per ton of destruction in this New Brighton plant.

MR. MORSE. — The present cost is somewhere about $1.28. That is very high, and it is because the plant is conducted not entirely for the purpose of destruction, but also for experimental purposes. And the capacity of the plant has never been reached yet. In other words, only about 30 tons are burned, whereas the plant has a capacity of about 60 tons. In ordinary work of this kind the larger the plant the less the operating cost, and when a plant has reached its capacity, the cost per ton is less than when it was operating below its capacity. I may say that, under ordinary conditions, the cost of operation without any

rebate from power and clinker would be from 78 cents, as in Westmount, to $1.28, as in New Brighton. They are now installing engines for electric service, and in a month or two we shall have returns which will show the application of the rebate to be recovered. It has never exceeded 80 cents at Westmount, and at the present time it is slightly less than that. At Vancouver it varies somewhere between 60 and 70 cents — I am not quite sure of the figures. In other words, the returns from rebates to be recovered from power and clinker are large.

MEMBER. — I'd like to ask Mr. Morse if he can give us any idea of what the approximate first cost might be to dispose of Boston refuse by destruction.

MR. MORSE. — Yes, in a rough way. Mr. S. A. Greeley made a calculation based on 20 or 30 destructors, and according to his tabulation the cost ran from $250 per ton up to $1 000, and the average was about $600 per ton of waste consumed. For instance, take a 50-ton plant; that would represent about $30 000 for the destructor plant only. Multiply that by the amount of waste in Boston and the result will be the approximate cost of a destructor plant here. Say a 300-ton plant is recommended — to give a concrete example; that would be, at the rate of $600 per ton, $180 000 for the initial cost of construction and installation. Add the cost of the ground and you have the cost of the whole plant. The Milwaukee plant cost $200 000 to install. That is practically at the rate of $600 per ton. I doubt if that could be repeated, because conditions are very exceptional. You might put down that the cost of installation of a plant would be somewhat between $600 and $800 per ton, and above that you could go into concrete and fancy construction, which means higher cost. The destructor people, I believe, put the cost at between $600 and $1 000 per ton, — the initial cost. And it is a permanent plant. The initial cost does not represent so much when you consider the plant will last from twenty-five to thirty years.

CHAIRMAN WESTON. — We should be pleased to hear from Mr. Emerson, the superintendent of streets of Boston.

MR. GUY C. EMERSON. — I came rather as a spectator. I arrived late and did not hear the first of Mr. Morse's remarks, and really I have little to say. I have been into the matter of garbage reduction and incineration somewhat extensively during the last two years, and I am not as optimistic as either Mr. Morse or Mr. Merrill in the matter. I am not prepared to dispute the statements which either of them presented, but

I want to warn the gentlemen present that whenever they go looking for figures they will find some peculiarity, either of natural conditions or something else, and very often a peculiarity of municipal bookkeeping that influences the result. The municipal plant in Montreal impressed me favorably. I was delighted to see the amount of coal they were saving by the destruction of refuse, but when I came to inquire why they needed two more boilers they said, "We use those all the time and only use the garbage when we can get steam for it." But I didn't find out how much it cost to run those boilers and how much the running of the refuse-fired boiler interfered with the operation of the other two.

In looking over the figures for Cleveland, the recent committee on refuse disposal were very much surprised by the profits shown, as stated by Mr. Morse to-night. But we found items that were a matter of opinion. In the opinion of the Cleveland managers, they were properly a credit to the working of the plant. We had serious doubts that such credits were warranted. We also found different conditions in every city. Cleveland, I am told, — I have not seen the plant, — has a plant located seven or eight miles from the city. In Boston a plant of that kind would be absolutely impossible. We are surrounded here by a population perhaps as large as that of Boston itself, and we should have to go perhaps 30 or 40 miles into the country before we could find a place where a municipal reduction plant would be tolerated. The islands of the harbor are perhaps the only available locations, and Mr. Merrill's company seems to have them pretty well tied up.

In the matter of the revenue to be derived from the products of incineration, the conditions in Boston are also somewhat different from those of other cities. Boston, as you all know, is a territory where sand and gravel are very cheap. They can be had almost for the taking away. Nobody, so far as I am aware, claims that for any purpose of construction, excepting perhaps for the building of concrete floors, where a peculiarly light material of concrete is needed, the clinker from an incinerator plant has as great value as gravel or crushed stone. Our commission were not prepared to recommend that any returns could be secured in Boston, or that some expense would not be incurred for disposal of clinker.

If any person has occasion to make up an estimate of the cost of refuse disposal in any city, I advise him not to take as a guide, without careful investigation, the figures advanced for

any particular city, but to go into the matter very carefully and make it, as both Mr. Morse and Mr. Merrill have suggested, an engineering problem for the specific locality they represent. And in that way they will get an idea of the problem and figures that will be more nearly correct. They may take the experience of other municipalities as to methods rather than as to expense.

Every incinerator plant I have investigated has claimed a certain price per ton for incineration. None of them has yet shown as low a price in actual operation. In the case of one plant I visited not long ago, if I remember correctly, the builders gave a guaranty of less than 50 cents per ton for the disposal of refuse. The superintendent in charge said they were disposing of it for something like $1.25 a ton. He thought if they had enough refuse to run the plant to its full capacity they might reduce the cost to 84 cents, and this condition seems almost universal. I am a little bit curious to see what is going to be the ultimate financial result of the guaranties and the bonds which the companies have been giving, when, so far as I know, none of them has reached the proposition which it guarantees, but at the present time they simply hold forth hopes and expectations.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1 1910, for publication in a subsequent number of the JOURNAL.]

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RIPARIAN BOUNDARIES.

BY PROF. J. B. DAVIS, MEMBER OF THE DETROIT ENGINEERING SOCIETY.

[A paper presented before the Detroit Engineering Society, March 18, 1910.]

THE boundaries here referred to are those which divide the area subject to riparian rights between the abutting land owners. The riparian rights of an abutting land owner are considered to begin at the edge of the water, and, proceeding off shore, to intermingle with those of the public. At the shore, private rights may be predominant. At a sufficient distance from the shore, the public rights may become of paramount importance. The off-shore boundary of riparian rights is indefinable, except in the case of streams. The division of the area over which riparian rights extend between the various shore owners, including the line of division of a stream, is that which designates the boundaries herein considered.

In the last analysis a boundary is a line, whether the call be for a lake, a stream, a shore, a wall, high water, or any other object. This line should be such as can have its location determined by survey. A rule for the location of a boundary which gives a different location of it at different times, or that is capable of being applied in more than one way, is a poor rule.

Herein it is proposed that riparian boundaries be the same on, or in, the water as they would be if the water imperceptibly receded. Riparian boundaries should be the same as the boundaries of reliction.

Boundaries dividing reliction, or lands permanently un-

covered by the imperceptible recession of the water, are simply lines of steepest descent proceeding from the termination at the edge of the water of the division lines of the upland. This form of statement may be used as a comprehensive substitute for the various forms of expression commonly employed in describing such boundaries. This line of steepest descent can be determined by survey, either before or after the water recedes. A contour map of the surface of the ground in question (whether covered by water or not), with a sufficiently small contour interval, would enable the line of steepest descent to be drawn on such map with any desirable nicety. In general such a line would likely be very irregular. There should be drawn upon the map a succession of straight lines following the irregular line of steepest descent as closely as may be desired, and defining an equivalent boundary. These straight lines should be adopted as the actual boundary. The exact location should be ascertained from the map and by computation. They should be connected with the boundaries of the upland by the same means. Verification of this work should be made in the field, and monuments be planted to preserve the location of these lines on the ground. Any additional measurements of distances, angles or ranges that will more securely bind the locations of these boundaries to the other surveys should be obtained, for purposes of record, during the field operations.

The edge of the water should be surveyed and mapped, this survey being well connected with the other surveys. If the edge water line proves to be irregular, an equivalent boundary line should be adopted, and a map location of the same made. This adopted line should be laid out on the ground, verified, monumented, and connected to the other boundaries. A record should be made of the map; of the descriptions of the lines and all their connections and relations to other lines; of the data, descriptions and witnesses, for all monuments and their connections with and relations to the lines; and also of any and every thing that will aid in preserving the location of the lines, or assist in their relocation. There should be better surveys, better maps, computations, descriptions, reports and records than for the uplands, because of the water.

Likewise streams should be surveyed and contour maps prepared of their channels. On such a map crosswise division lines of steepest descent, proceeding from the shore ends of the division lines of the upland, could be drawn and continued to the lengthwise division line of the stream. The location of the

lengthwise division line of a stream could be made on such a map. Here again the doctrines that would apply in case the waters imperceptibly receded may be utilized while the water is yet there. These would make the lengthwise division line of a stream the location of the stream when about to disappear. This line can be determined upon a contour map with the aid of cross sections of the channel. All of these lines should be treated in the manner outlined above for other riparian boundaries, as to map location, computation, connections, field surveys, verification, monumenting, final maps, descriptions and record. The edge water line on both shores of the stream should be surveyed, mapped and recorded in the same thorough manner.

In all cases of surveys of riparian boundaries the elevation of the water should be taken, and, by gage readings if necessary, all the work should be referred to the same stage of water. In the case of streams the water elevations should be taken frequently enough on both shores to accurately define the water surface to which the surveys apply. All these elevations should be referred to permanent bench marks, and, wherever practicable, connected to the bench marks of extensive surveys. All of the information relating to elevations should be made a part of the permanent record of the work.

It has been held that riparian boundaries are not worth surveying. Especially might such a remark apply to the thorough work here called for. Riparian rights, or certain of them, may be sold, or leased, separately from the upland. Such are ice cutting, oyster shore, fishing and landing privileges. Good surveys and records would aid in delimiting such conveyances, more than in almost any other class. So far as cost goes, an examination of the reports of law suits over ice cutting alone might readily lead to the belief that surveys at almost any cost might be a profitable investment. The most important consideration is the reduction or prevention of litigation, especially of the merely contentious kind. It may well be doubted if any court would attempt to change, alter or disturb a boundary, however arrived at, which had been surveyed, mapped and recorded as herein specified. The record itself would be evidence of a certain deliberate consideration in arriving at the location recorded, not lightly to be cast aside. Such surveys and records furnish a point of departure for future transactions. Presently the steadying effect of their existence would be worth all their cost.

The uncertainty of location of riparian boundaries is due to several facts.

There seems to be no general principle applied to their location.

The terminations at the shore of the division lines of the upland were not ascertained and recorded when the first surveys were made.

The shore line was not surveyed, mapped and recorded.

The stage of water was not ascertained, marked and recorded at the time of the first or original surveys.

The land beneath the water was not surveyed, mapped and recorded at the time the boundaries of the land above the water were.

The shore line changes.

The shape of the land beneath the water changes.

The off-shore boundary is either indeterminate or uncertain.

For centuries courts have been asked to define boundaries, when neither terminal, nor the direction and extent of any course, could be known. Such are the division lines of riparian rights or ownership. The endeavor seems to have been to do justice as nearly as was practicable in each case. The results are hardly to be regarded as a consistent legal structure based upon sound principles. Really, the courts appear to have needed much information they did not have, which might have been supplied by surveys and examinations that were not ordered, and it is conceivable that the advice of an engineer of experience might have been of material assistance ofttimes. Perhaps the riparian boundaries defined by court decree have been laid out on the ground, marked, mapped and recorded, but if such is the case, it is unknown to the writer. The impression is gained from reading decrees in such cases that the matter at issue in many cases is left to be contested again, at some future time, with the added uncertainties due to the lapse of time, and further complications introduced by the inability to find out on the ground the location named in the decree. It seems very desirable that good surveys should be ordered, the lines carefully laid out on the ground and monumented, maps be made, and records of all this work, properly authenticated, be preserved. If for no other reason, it seems as if these things should be done to fix and establish a place of departure for future transactions. But there are other reasons, one of which is that we might be able to look forward to the time, however far distant, when this class of troublesome and puzzling cases should become reduced in number and much restricted in uncertainty, making things plainer for the courts

and the people, — a public duty worthy of the best efforts that can be bestowed upon it.

The riparian rights or ownership which have descended by conveyance to the present owner of a piece of land with a water front must in general be those attaching to that land at the time of its original survey and sale. The boundaries of these rights are unknown. Their shore ends, at the terminations of the upland boundaries, are unknown because these terminations were not ascertained and recorded when the land was first surveyed. The off-shore end is unknown, being either indeterminate or uncertain because depending upon the fixing of the boundary of adjacent property, as the "thread" of a stream. The direction and extent of any course in such a boundary depends upon the configuration of the ground beneath the water at the time of the original survey of the land above the water, and this configuration was not then made the subject of a survey and record. The shore line boundary of riparian rights — and also of the upland — is unknown because the edge-water line at the time of the original survey was not surveyed and recorded. Neither was the stage of water taken, marked and recorded, to which the original survey applied. This last fact removes the opportunity for even a guess at the location of the shore-line boundary of the riparian rights, or of the upland to which they attached. The surveys of the upland often were not closed at all, the acreage being hardly more than an estimate, with no clew to the basis of the estimate. Sometimes closing lines were run and a correct calculation of area made, but without a record of the closing lines being preserved, or any evidence showing whether the computed area extended to the edge of the water or not. In the case of the public domain, meander lines are specified to close the survey of every piece of land, but meander lines do not follow the edge of the water, neither are the meander corners between which they run placed at the edge of the water. There appear to be no original surveys of land boundaries which embrace the water and the land beneath it. Every item of information is lacking upon which could be based the location of the boundaries of the riparian rights originally attached to the upland, and which are the only riparian rights descending by conveyance to the present owner from the original grantors. Amongst the flotsam of the unstable waters appear to be the original riparian rights in those waters, with no prospect for their recovery. The courts will give something of like nature in their place. This is the best that can be done, as the original rights cannot

be recovered; but it seems fair to ask if what the court gives should be left to pass out of reach like the original rights. Under present conditions, the purchaser of shore property cannot know what the limits of his riparian rights will be. Neither can he be shown.

Riparian rights, or certain of them, may be sold or leased separately from the upland. Such are ice cutting, fishing, landings, oyster shore. The limits of these grants or leases cannot be defined as things now are.

Riparian rights may have to be defended from encroachment, injury or even against destruction. The very first thing in such cases that must be known are the limits, and these cannot be defined. Such cases may arise from trespass, discharge of waste, discharge of sewage, pollution of water, or because of structures that cause a change in the depth of water or in the regimen of a stream.

In lawsuits over riparian rights the definition and delimitation of these rights is the first work of the court. This may be a matter of far more consequence and difficulty than the subject of complaint. Under present conditions this means, or is likely to mean, a new determination of what the riparian rights and their limits are at the date of every new cause, because of the lack of surveys and records of the limits fixed by previous decrees. The whole situation is made more difficult and complex by the different theories upon which the statutes of different states are based, and by the different methods employed by different courts in defining riparian boundaries.

At times, shore frontage and riparian rights have been divided:

By lines perpendicular to the bank.

By lines perpendicular to the channel bank.

By dividing a new shore line in the same proportion the old one was divided and joining the points of division on one shore to those on the other shore by straight lines.

By lines perpendicular to the thread of a stream running back to the points of division on the shore.

By dividing the area of reliction in certain proportions.

Physical conditions on the ground may render any of these methods impracticable or impossible, and the court is without the aid, advice or assistance of its own engineer. In most of these methods there is involved the question of determining what areas over or on which riparian rights apply are "opposite" a certain tract of upland. Seldom is this easy to do; often it

is impracticable; yet the court remains without information regarding this fact. When the division lines are made perpendicular to the bank or the thread of a stream, a careful analysis of the decree will show that it really requires the banks of the stream to be parallel. Frequently, especially in Michigan, the division lines are made perpendicular to the channel bank. I have never been connected with a case where a channel bank could be found, — there was none, — yet the court was without information of this fact, probably. Where courts have defined the "thread" of a stream, reference is had to a line midway between the edge water lines of the stream, with no mention of the stage of water. This gives a different "thread" for every different stage. I know of no surveys of any "thread" being mentioned. If the "thread" be different for different stages of a stream, the division lines of riparian rights that are to be perpendicular to that "thread," and to strike certain designated points on the shore, will likewise be different for different stages of the stream. So far as I know, the division of areas of reliction between abutting owners by proportion is quite as uncertain and impracticable as any method.

The fact that water frontage may be lost to a piece of shore property seems to be not recognized. In consequence, some of the division lines of reliction which have been specified in a general way cannot be laid out on the ground. Water frontage may be lost in a number of ways. A stream may change its channel, or it may entirely disappear. Upon the subsidence of the water an island may be connected to the main land and the water front on that side be lost. In the case of bays, bayous, points and peninsulas, the subsidence of the water may deprive lands of their water frontage. These subsidences may be beyond the control of man. The courts have done their best to preserve a water front for the land that had one before the change in the stage of the water. Possibly it might have been better to have treated the water front as lost to some pieces of land. Possibly, if all of the facts on the ground could have been presented to the court by an engineer of experience, acting under a direct order of the court, a different conclusion would have been reached in some cases.

An engineer should decline to undertake surveys where calls are made for things to be done which are geometrically inconsistent with one another or with the facts and conditions on the ground. If such inconsistencies are found after a survey has been begun, he should report the facts and ask for further

instructions. If instructions consistent with the geometrical and physical facts in the case are not provided, he should stop his survey and withdraw from the work, notifying all parties directly concerned. Of course such notice had better be written. This does not mean that the engineer should assume an attitude either hostile or critical towards the parties concerned with the survey; on the contrary, it is his duty to render every assistance he can in clearing the tangle. It does mean that he should neither forget nor ignore his obligations as a professional man under the law, and that he should not assume responsibilities that do not certainly belong to him, as has been done far too frequently, often only to his own injury and the addition of further complexities to a situation already confusing.

Engineers should decline to make surveys for clients, and prepare maps and reports regarding the same, in law cases when any restrictions are imposed limiting the facts, data or information to be exhibited. The court is entitled to know all there is to be known about the facts in any case which is before it for adjudication.

If the division lines between riparian rights could be made lines of steepest descent, as herein advocated, while it might simplify the specification and location of such lines, it would not remove every difficulty connected therewith. The size of the body of water to which the rights applied, and the uses to which it is or is to be put, would have to be considered in deciding upon the proper contour interval and what should be regarded as the characteristic contours normal to which the division lines of the riparian rights should be drawn. It is easy to conceive of a conformation of the bottom that in case the waters receded might deprive an abutting owner of his water front, or might give him possession, in whole or in part, of a small pond while he was cut off from the main body of water, or might leave him an abutting owner on a bayou, or channel, connecting with the larger body of water by a long and circuitous route past the lands of others fronting on the same bayou or channel, in place of the direct access he had enjoyed before the recession took place, — in short, the recession might set up entirely new conditions and destroy the old ones. Such possibilities should be deliberately considered in deciding upon the location of the division boundaries upon original surveys, or those which take the place of original surveys that were not made, because when these boundaries become fixed in a proper and lawful manner, courts will justly be slow to modify them — and there should be no occasion

to do so. The problems presented by islands, bays, bayous, points and peninsulas of small size would still be serious enough, but it is believed their resolution would be considerably simplified as compared with present-time methods.

Once the riparian boundaries have been located, surveyed, mapped and recorded, the subdivision of a piece of land with a water front should proceed within the limits of the original survey and the riparian rights attaching to each parcel in the subdivision be laid out to conform to the conditions at the time the subdivision is made and recorded.

As a riparian division line should begin at the edge of the water, the edge water line should be surveyed, mapped and recorded, — also the stage of water, as before pointed out. However, the division lines of the upland were seldom extended to the water's edge. How should these lines be extended to the water's edge in order to locate the points from which the riparian division lines should proceed? As the strip of land over which they are to be extended is not always narrow, because of swamps, marshes, morasses and faulty original surveys, this problem of itself is not a simple one. Where traces of the original water line can be discovered (as is more frequently the case than is sometimes supposed), the upland division lines may be extended directly to this old water line. If there is reliction, and the surface has not been seriously modified, follow the lines of steepest descent from the old water line to the present water line to get the starting points for the riparian division lines. If there is accretion, or the surface of the reliction has been seriously modified, two courses are open; one is, by subsurface examinations seek the original surface of the bottom of the water and follow the lines of steepest descent thereon; the other is, to ask for a subdivision of the land between the ends of the upland division lines and the water as it stands, either by agreement of the parties in interest or by a suit at law, thus fixing on the new water line the points from which the division lines of the riparian rights shall proceed. In the case of swamps and marshes, or similar deposits, one or another of the above suggestions may be followed.

Summary.

A boundary is a line, and should be one that can be surveyed.

The rule for defining a boundary should always locate it in the same place.

Survey the water and the land beneath it, as well as the upland.

If not heretofore done, begin at the next opportunity.

Survey, map and record the edge water lines.

Find, mark and record the stage of water at the time of survey.

Record all the information gathered.

Riparian division lines should be lines of steepest descent.

The " thread " of a stream is the stream when it becomes a thread.

Make and preserve contour maps of all field operations.

On these maps mark and define the riparian boundaries.

Make copies of these completed maps a part of the public records.

Ask the courts to define riparian boundaries so they can be surveyed.

Ask the courts to require surveys, maps and records of the lines defined by decree in riparian cases, and ask that these maps and records be made a part of the files in the case, if they cannot be spread on the records of the deeds.

Ask the courts to order surveys of their own for their information.

Possibly courts might profit by the advice of experienced engineers, in the employ of the court, in considering riparian boundaries.

Engineers should decline to try to lay out impracticable lines, or to make incomplete or defective surveys, for court use.

It is not proposed to use any new principle, but to apply an old, well-established one to riparian boundaries.

DISCUSSION.

The Chair. — Gentlemen, we have had a subject placed before us that in some cases Professor Davis tells us the engineer should put up to the courts. They have various things to say about this, and, as nearly as I can gather, they are to order us around, and tell us what we are to do about it. We as engineers would hardly know where to begin at that, but fortunately we have with us this evening some gentlemen who are in touch with the legal aspects of the case. I have no doubt that Mr. Goff has some thoughts that have been brought out by this paper of Professor Davis's, and if he would kindly let us hear from him, I am sure we should be very much obliged.

Mr. John H. Goff. — Mr. President, the duty which devolves upon me first, as well as great pleasure, is to acknowledge

and confess my appreciation of your kindness in asking me to be with you to-night, and to be brought in immediate contact with and to make the acquaintance of so good a man in his line of business as Professor Davis. I appreciate deeply your courtesy, and wish that the ability was on my side to give to you a discussion of the legal aspects of the paper or the topics that have been drawn upon by Professor Davis. That, as I take it, is not expected to any large degree.

Professor Davis has touched upon this subject entirely from the surveyor's standpoint. When the invitation was sent out by your genial secretary, a smile came over my face, because I understood from reading the secretary's letter that Professor Davis would discuss riparian rights, and then I began to think that if the professor would discuss riparian rights, there would be an opportunity for more or less pleasure, because he would get on to our ground, the legal side of it, and probably we could have a lovely time. But I then got a letter from the professor, stating exactly where it was he stood, — that his subject would be riparian boundaries, and desiring me to understand, as well as others, that he was not interfering at all with the business of courts, and consequently would not discuss riparian rights. I have been thinking, as the professor was talking, how the general scheme that he suggests could be brought about. In starting such a project as the professor has in mind, I doubt whether you could have a general scheme operative all over the state. Sometimes engineers get into their heads the idea that they establish lines. I have listened carefully to the professor all the way through, and if he at any time spoke of establishing a line or a corner, he immediately said "locate," or something of that kind. The old man in the service, the man that has been in the courts, carefully avoids talking about establishing anything. [*Laughter.*] The young man just fresh from the schools, feeling his oats, as we have all felt them, — no crime at all, — put him on the stand and you will frequently hear him say, "I established that line, and I established that corner." I want to read to you a little bit what the courts say about this, and what they said at a very early date in Michigan. That was at the time the Big Four sat upon the bench, and, therefore, you can understand that this language is chosen language:

"It appears to have been supposed that surveyors are competent, not only to testify to measurements, and distances, but also to pass judgment themselves, and on information of their own choosing, upon the position of lines and starting points.

This is not the only case in which we have encountered such evidence on important private rights. Surveyors seem to have the idea that they may act entirely on their own judgment in determining important private and public rights. This is a very dangerous error. The law recognizes them as useful assistants in doing the mechanical work of measurement and calculation, and it also allows such credit to their judgment as belongs to any experience which may give it value, in cases where better means of inspection do not exist; but the determination of facts belongs exclusively to courts and juries. Where a section line or other starting point actually exists is always a question of fact and not of theory, and cannot be left to the opinion of an expert for final decision. And where, as is generally the case in an old community, boundaries and positions have been fixed by long use and acquiescence, it would be contrary to all reason and justice to have them interfered with on any abstract notion of science."

The last paragraph is what I call your immediate attention to:

"The freaks of opinionated surveyors have led to much needless and vexatious litigation and disturbance, and it is much to be desired that they should be confined to their legitimate place as witnesses on fact, and not on opinions which lie beyond the domain of science."

So, if we apply that to the theory that we would now survey these riparian rights, you must bear in mind that the genial surveyor will have to find some old lines before he can make any new ones. So if he goes to making a record and having it recorded, then you will have to be guided very carefully by the law that will be laid down for him. Many people think: "If I have a county surveyor go and survey my lines between myself and my neighbor, if I have the county surveyor survey it and he gives me a certificate, that settles it. He is the county surveyor, officially recognized as such, and so when he says the line is here, and the corner is here, why, it must certainly be there, and I will have his writing for it." Now, the law says in regard to this county surveyor, first, that the certificate which is prepared by him must set forth certain things. The first thing that it requires of him before his certificate is good for anything at all, — before it is worth anything more than waste paper, — is that he must set forth in that certificate the evidence by which the surveyor determined or identified the corners, or other starting points of his survey, and the means taken to perpetuate them on the ground. That is the first thing. Second, the objects of the survey, methods pursued by the surveyor in making it, illustrated by

diagrams. Third, amount and direction of allowance made by the surveyor for the difference between the magnetic meridian and the true meridian. If he goes to survey a private land claim, or anything of that kind, at the present date, with the needle, the law says he must give in this certificate the amount and direction of allowance made by the surveyor for that difference. Now, after he has done all those things, after he has got them all in, — and I have only given you a brief abstract of what he must put in, — then the law says that record of the survey of the county surveyor is presumptive evidence of the facts found therein. That is a pretty cautious statement. It is presumptive evidence. You will notice that the law carefully avoids stating that he establishes anything or that the survey establishes anything. It is only presumptive evidence. Now, he makes his certificate, and you will remember that it is possible that his certificate is brought into court, and when it gets into court, another surveyor will get on, and a very competent gentleman, lately brought on, who understands his business down to date — they are always making improvements in everything. He will take that paper, and he will point out — he possibly has been instructed by some man who is up to date, and even a young man in his business will take the survey of the county surveyor — and he will say, "Your starting point was not right. You started here and you measured from what you call a certain post, but if you had started a few feet farther to the west, you would find a monument there that is recorded in the original survey, everything so perfect that it cannot be disputed by mortal man, and you started at what you call a post or a stake." Now, he says, "You are wrong. My measurement shows you to be entirely incorrect on that." Then the law says that the presumptive evidence is overcome. Consequently, the matter is set at large, and your twelve men sitting on the jury will tell you where the right line is, because, after all, it is simply a question of fact.

But I believe there are others here who are to talk to-night, so I have just given you a brief outline. I must say that I approve very much of the professor's remarks, and think that, with proper allowance and care so that the surveyor would not have anything established, and would take away our business entirely [*laughter*], — there would never be any law business after that is got through, you know, we would not want anything of that kind to be done, we would be opposed to that, of course, — but anything that would go towards establishing a sort of a presumptive evidence as to where your riparian boundary was,

would be welcomed by the legal profession. I thank you very much for your kindness. [*Applause.*]

The Chair. — The water seems to be making us a good deal of trouble to-night, in one way or another. I don't know when I have found it such a difficult matter to see through it. It makes me think of the Chicago River that used to be when I lived there — I believe it has changed its character. I don't know whether there are any of the riparian boundaries on the Chicago River that have been changed about, but in connection with riparian boundaries and riparian rights, the character of the body of water always seems, well, frequently at any rate, seems to come in; and Mr. Perry has consented to tell us something about the different ways in which some bodies of water can be looked upon.

Mr. George B. Perry. — *Mr. President and Members of the Detroit Engineering Society,* — I want to assure you, first, of my appreciation of the invitation to come and say a few words. In addition to all the engineers, I see also here some lawyers, and I am quite certain that I shall probably get into a fight with them before I get through. So I am very much embarrassed. But to carry out the idea of Professor Davis' paper, I thought I would say a few words which might be of practical importance to engineers, and that is to state as well as I am able to state the prevalent rules in Michigan to-day regarding the running out of lines in Lake St. Clair, from the property which is known as Grosse Pointe Farms. This becomes important, it seems to me, because you are liable at any time to be asked to draw plans for a dock or wharf from shore property on Lake St. Clair. The direction in which you can build that dock is of very great importance to the land owner, and is of very great importance to you professionally.

At a very early time in the state of Michigan, the Supreme Court decided that the title to the lands in the rivers of the state belonged to the adjacent land owner. In that same early time, the court used some loose language which made it appear that the title to the bed of the Great Lakes also belonged to the land owners who abutted on the Great Lakes, but after a little while the Supreme Court changed around, and the Supreme Court now holds that title to land in the Great Lakes beyond the meander line belongs to the state of Michigan, in trust for all of its citizens. Therefore we have the anomalous situation that land out here in the Detroit River, to what is very erroneously called the thread of the stream, belongs to the adjoining property owners, and the land in Lake Erie down below the meander line belongs to the

state in trust for its citizens. I suppose that goes so far as to say that anybody who owns land on the Detroit River, in the absence of any statute, can stop anybody from fishing or shooting in front of his land. On the Great Lakes you cannot stop anybody from fishing and shooting below the meander line. But whether it is the river or lake, you have an undoubted right to build a dock or wharf as long as you do not interfere with navigation, and as long as you do not interfere with the rights of other people; and probably in places where the United States has established what is called a " harbor line," you have a right to build a dock out to the harbor line. Now, the United States has established a harbor line in the Detroit River, and has established a harbor line which is a considerable ways from shore in Lake St. Clair, and, if it became necessary, you probably could build on the proper piece of land in Lake St. Clair out to that harbor line; but it does not become necessary because there is a line of navigable water inside of the harbor line on Lake St. Clair which is plenty deep enough to float any boat that can get in there, and any boats that can sail at all upon the Lakes. Now, the Supreme Court of Michigan has never decided what land a person on one of the Great Lakes owns in front of his shore property if he is situated on a straight shore. They have decided that on a river, if you are situated on a straight shore of a river, you draw a line perpendicular from the side of the stream to the side lines of your property. That is, on a straight shore in a river, the law in Michigan. But that does not have any very great application to a situation where there is no thread, and there is no thread in Lake St. Clair. Now, they have also decided, adopting a rule which they originally brought from Massachusetts, with regard to a curved shore, — which is the situation in most of the places in Lake St. Clair, — that you draw a line between the two head lands of the curve, and that line should go along the line of the fairly navigable water. The Supreme Court of this state has chosen, in at least one case, water eighteen feet deep. Then you measure the number of feet on the curved shore and you divide the line between the promontories of the curve into as many equal parts as there are feet on the shore. Then you divide the proportionate number of those equal parts to the number of feet in each individual land owner's holdings, and draw lines between them, and that is the way the Supreme Court of Michigan to-day says that you determine the holdings of land underneath the water in the Great Lakes on a curved shore. Now, that is all very well, but there are lots of curved shores such that you cannot draw lines from all parts to a line

between two promontories. They call that line between the two promontories a base line. So when you have got to a situation where they cannot reach one base line, they establish another one. They establish a line nearer to the shore which they can reach from all parts of the land, and they divide that up in that proportionate way, and then they draw lines from the first base line to the second base line. If you have got a deep bay, sometimes, in accordance with the laws of Michigan, you have got to draw four or five base lines to find out how your line goes out into the water, because there is a great deal more land on the shore than there is land out in the water to equal.

That is the situation with regard to the curved shores along Lake St. Clair, and it is extremely difficult to say, except as I have tried to explain it, just how to advise anybody to draw the plans of a dock in front of any property. But those are the two rules of law which the Supreme Court of Michigan has laid down as the law of Michigan on this subject.

Now, with regard to a shore on Lake St. Clair which is straight. I have said they never decided how you draw lines on a straight shore in a lake. But they have said in some cases that the laws which affect lines going into the ocean would better apply to bodies of water of the size of Lake St. Clair than the drawing of lines on rivers. I take it that the Supreme Court of Michigan would very probably, in the case of a straight shore on Lake St. Clair, find out in some way or another — and Professor Davis has amply showed us that it is impossible to find this out (but they will find it out) [*laughter*] — just where this proper depth of navigation is, and just exactly in what direction they think it runs. Then they will say that you draw lines at right angles from that line of navigation to the shore lines of the property. Now, I do not mean by that that your land stops at the line of navigation. I am not trying to discuss where the upland owner's land underneath Lake St. Clair stops, because nobody knows anything about that. But in determining how to build a dock on a straight shore, I think that they will take a line which they will assume to be the line of navigation at a certain depth and draw those lines perpendicularly from the line of navigation to the boundary line of the property. I thank you very much. [*Applause.*]

The Chair. — The Soo River has caused us a good deal of trouble at one time or another, or at any rate some of the members of this society. I think Mr. Dow had some troubles with the rights up there at the Soo, but I don't know whether that came

exactly under this head. He probably has something to suggest on the subject.

MR. ALEX. DOW. — *Mr. President*, the Soo River matter is one about which Mr. Goff would be more capable of telling you the legal points than I am. The matter has so far taken a peculiar legal turn; but, subject to Mr. Goff's correction, and preserving my right to disagree with my lawyer, —

MR. GOFF. — You are not binding yourself to anything. [*Laughter.*]

MR. DOW. — Not binding myself to anything, I will tell you briefly just the situation there. It certainly illustrates very clearly the difficulty which Professor Davis has pointed out to you. In that river, the thread of the stream is an international boundary. It has never been marked, and no law until last year was provided for its marking. Last year a treaty negotiated with Great Britain, — virtually of course, with Canada, — provided for the marking of the boundary according, as I read the treaty, to the intent, as near as it can be guessed at, of the commissioners who in the treaty of Ghent — treaty of what year, Mr. Goff? 1822?

MR. GOFF. — Treaty of Ghent?

MR. DOW. — Yes.

MR. GOFF. — The commissioners established that in 1822. It was a commission.

MR. DOW. — Eighteen hundred and twenty-two, as nearly as can be guessed according to the intent of the commissioners, who marked in a large, broad-minded way, the boundaries on a certain map in 1822. The rule in the treaty provides that where the boundary on that map is a curved line, it shall be described by convenient tangents, which of course is only common sense. The division of land on the Soo River between riparian owners at the point where that division was a matter of great monetary importance because of the water power, has ceased to be anything — or will soon cease to be anything — but an academic question. There still remains one question, one suit, in which that division will certainly have to be defined and decided. And inasmuch as it is a suit which will come to trial within a little while, my expression upon it must be subject to correction by what Mr. Goff has pointed out to be the ultimate authority, the courts. The question is, to begin with, Where is the thread of the stream? The Michigan rule unquestionably applies, that you start from the water's edge and go out from your mark on the water's edge to a point normal with the thread of the stream.

The thread of the stream is a rather indefinite proposition. It may be decided to be the ultimate thread if there shall be a continuing recession of the river. It would be capable of determination in that way; but the engineer who should undertake to determine just what the thread of that stream would be if the river should run dry, all but the last thread, — well, he has my sympathy. I have had occasion to determine some things out in those rapids, and to determine them with sufficient accuracy to warrant the spending of several hundred thousand dollars on the strength of the determination made, and I assure you — there is a reef about every four hundred yards, and the river is mostly upon end at that reef — the location of the final thread is somewhat of a puzzle. And while Professor Davis has suggested the rule which would ultimately locate the thread, the location in that case would probably be completed about the year of Grace, I should say, 2100. The question of projection has been complicated by assumptions. There were a lot of assumptions in the early days on that river. One of them was that there was plenty of land and plenty of water for everybody, and it was only a matter of very recent years that the determination of riparian rights has become important. As I say, the final rule will probably be laid down in a case that will come into court within a month or two; and after it is laid down, it will cease to be of any great practical interest, because the United States has actually taken possession of all the land abutting upon the rapids, and the case in question is merely to determine damages in a condemnation suit. That rule will, as I say, after that suit, be of no interest to anybody because the United States will be the only owner along the rapids. A question came up, however, on the Detroit River, of an exactly similar character, the location of a fence line between the Government reservation of Fort Wayne and the next south property owner. At the time that question came up I was of record the next south property owner. The actual owner was the Edison Company. The fence was an old landmark. It was very crooked, exceedingly crooked. The correspondence, which followed the usual slow and deliberate and thoughtful course of correspondence with the Government Department, took several phases. The first was, that it was necessary to make it quite clear to the Government that that fence was very crooked, that it was not by any means such as would represent any survey line on any map or any record whatsoever. That fact having been made sufficiently clear, the next proposition came with regard to the projection of the line northward towards the road.

A little piece of land had been left out over night and appropriated by the people who passed title to the Edison Company. The authorities in Washington promptly announced that the survey, as they referred to it, would give that piece of land to them, and that they were in possession at the lower end. They were not in possession at the upper end, but the statute of limitations, which would give the westerly owner possession, did not run against the Government. The Government was in possession at the lower end, and of course the statute of limitations would run in favor of the Government. It took some time to settle that matter according to one rule or the other, the respectful representation by myself, at least by the correspondent in the matter, being that it was a mighty peculiar statute of limitations which ran at one end of a fence and did not run at the other. The location of the lower end of the fence became important, because that was the apparent location of the water line. After much discussion, they decided that the last post in that fence was probably put there at or about the water line with the intent to stop cattle going around it, and absolutely by agreement between the parties, not by any fixed rule or any fixed survey, the post was accepted as being the original location of the survey water line, and as the point of departure for the projected riparian line. Then another assumption was adopted, which was that the harbor line established by the United States engineers was substantially the thread of the stream, or equivalent to the thread of the stream, and a line normal from that to this post would settle that boundary, which of course was entirely satisfactory. But you will notice that in each case the matter was ultimately a matter of agreement; and the final determination was by the exchange of deeds from the United States to the next owner west, and from the next owner west to the United States, each giving title to the land beyond certain marks agreed upon between them, and now represented by a substantial map. It became perfectly clear, even to the authorities in Washington, that neither survey nor law was adequate for the settlement of that fence line, and it ended, as such things should always end, in an agreement that is substantially equitable, and in the erection, I am glad to say at the expense of the Government, of a quite substantial fence. A most amusing interlude, rather alien to this question, but still showing just what will happen when people insist upon sticking to surveys, occurred in the shape of an order to the commandant at the fort to reëstablish that line — I think I have the expression correctly — according to the original sur-

vey, and to occupy that line. A somewhat unofficial notice of that was given to me, and I was told this was not official, but that was the instruction given; what did I unofficially think about it? I said what I was thinking about it was, right now, what I should do with the southernmost officer's house, that I should be very glad to have it established on the basis of 1840, but that would give me a very nice residence, and I didn't know whom to rent it to. The truth was that the surveyor who put in the stakes for the Fort Wayne property took all that was coming to him and something extra. The man next to it staked out his private claim line from that, and the shortage was pushed on until it ran against the River Rouge, and fortunately a stake out in the River Rouge would not hold. That was navigable water. Then the man at the River Rouge started back again, and it resulted finally that one lot, which I am sorry to say was the one that I got, was left with a shortage of about forty feet. In each case the necessary period of limitation had run, and the position of the fence at the river had to be settled in some way. I don't want to give away a fellow member of this society, but I will say that the final position of the water stake at the river was not exactly established by reference to a cow fence or anything of that kind, but that inasmuch as it was a matter of considerable argument, and the water line was different on different days, and each surveyor had his own water line, that the two of us matched quarters, and again, I regret to say, the other fellow won. [*Laughter and applause.*]

The Chair.—Well, we have had a large amount of discussion here about navigable waters, and now and then the Government has come in for a slap of some kind or other, and I am very sure that Colonel Townsend must be simply boiling over. We don't want to have anybody really suffer, so if Colonel Townsend will say something to us, we would be much obliged.

Colonel Townsend.—Gentlemen, this question of riparian rights is something that I thought was going to be treated in a little bit different manner than it is. Instead of riparian boundaries it was a question of riparian rights. I have listened carefully to what has been said, and I intensely appreciate what the last speaker had to say. All my surveying for the army was in the Philippines. I happened to be out there as a division engineer, and I got up against some quite interesting surveys. Among other things, I found a military post, where all the officers' quarters connected with that post were on private land. The post was very well located, and they had got it very nicely

fixed, but they had put the houses entirely off the reservation.

In listening to this talk I have been very much impressed with the very serious proposition that arises with the officer who is in charge of works of improvement, and that is that these riparian rights which you are talking about are rights that the Government does not have, and I brought down here a paper or two that I would like to read to you, just to show you what few rights the Government of the United States has. I have here an opinion from one Senator Nelson. He has written an opinion in a report on water rights of the federal Government and of the various states. Here is the statement:

"That each individual state of the Union has control of the waters of navigable streams and lakes within its borders, the right and interest of the United States in such waters being only that their navigability be preserved for interstate commerce."

He then quotes a number of decisions of courts that I won't bother you with. That decision is a very vital one for an engineering officer who has charge of doing the work which I have. In other words, riparian rights do not exist in the United States. They exist in the state; and I have had a number of experiences that were quite interesting to engineers on that line. At one time I had to construct levies along the Mississippi River in the state of Louisiana, Arkansas, Mississippi and Iowa, and, governed by that very principle, I had to apply the law of the different states in doing the work of the Government, and I will tell you how it worked. In Louisiana, the land along the Mississippi River was acquired under Spanish grants. Those grants put a servitude, as the lawyers call it, on the land, that they gave the land to the grantor for the purpose of building a levee. The result was that that servitude existed for the rest of time on the land, and you could build a levee in the state of Louisiana, go right through any man's property, and there was no compensation. In the state of Arkansas, when you attempted to build a levee, the law of the state of Arkansas was that you would take the advantage you gave to the man and oppose it to the injury you did him, and if you benefited him more than you injured him, then you did not compensate him; but if you injured him more than you benefited him, the difference you paid to him. That I consider about the most just law that I experienced down in that country. But, in building levees in Mississippi, they have a different law. You not only had to pay the man for the land that you built your levee

on, but you had to pay him for all the land that you threw out of the levee land; and there you get a very serious proposition. It got so serious that it paid better to build the levee where the land would cave into the river in a year or two than it did to put a levee where it ought to belong. You could build a series of levees every two or three years much better than you could build a levee where it ought to be, and to pay a man for the land that was outside of it. There is an illustration of what an officer of the Government had to do in three different states. The next state was Iowa, and I also had to build levees, but there we compromised with the people and made them give the land before we would build a levee.

In talking of these riparian rights, and as showing you the difference between states, in building locks on the rivers of Pennsylvania, — on the Monongahela River, for instance, — we can go to work on the Monongahela River and build a lock and we do not have to condemn a lock. That is a peculiarity of the state of Pennsylvania. The owner of the land owns down to low water, but the state when it entered the Union retained in some way a power up to high water, and the United States can go in there and build a lock between high and low water, and does not have to condemn the land. But we go down the Ohio River into the state of Ohio, and we have got to condemn the land and buy the land to do exactly the same thing.

Now comes up another very interesting proposition, that we are getting into now recently, and that is this question of water power. We are having a great deal to say about the United States conserving the water power to the people. The United States has not got a thing to do with the water power, except in cases where it has not sold the land. The public land out in the West that it has never sold, the United States can hold; but if it has ever sold those lands, those lands go to the state, and there are some very interesting things in reference to that. You come here in the East and the common law applies. I just brought this paper with me, because I don't like to read law without anything. But here is what Mr. Kent says in reference to the common law:

"That every proprietor of land on the banks of a river has a natural right to the use of the water which flows in a stream adjacent to his lands, as it was wont to run, without diminution or alteration. No proprietor has a right to use the water to the prejudice of other proprietors above or below him, unless he has a prior right to divert it to some exclusive enjoyment. He has

no property in the water itself, but a simple usufruct, as it passes along."

I will omit considerable Latin here. Its translation is:

"Though he may use the water as it runs over his land as an incident to the land, he may not unreasonably detain it or give it another direction, and he must return it to its ordinary channel as it leaves his estate."

That seems to be the law of our eastern states. But our western states have another law, and that is what is called the "doctrine of prior appropriation." In accordance with the doctrine of prior appropriation, the person who first appropriates the water of a stream for beneficial use has the first right thereto, whether he be a riparian owner or not. Then there are a number of quotations in reference to that. Then, as far as I can make out, there are a number of states that have got laws that cross between these two methods.

I have got before me now quite an interesting question for lawyers. I happen to be on a board which has to consider the question of the waterway from Chicago to the Gulf, and I think it raises more interesting questions of law for an engineer to discuss than any that I have ever seen. There happens to be, in the first place, the Desplaines River and the upper portion of the Illinois River, which is considered by the Engineering Department and by the Secretary of War as a non-navigable waterway of the United States, its normal flow being under five hundred cubic feet a second. As far as I can find out, according to the laws of the state of Illinois, in a non-navigable waterway in the state of Illinois, any water-power rights that exist belong to the riparian owner. There is one question to consider. Now comes in the state, or the Sanitary District of Chicago, and it spends some fifty-six millions of dollars digging a ditch from Lake Michigan, connecting with this Desplaines River. Now, our friend Chancellor Kent in this discussion says that the proprietor when he uses water must return it back to the state. Well, the Sanitary District is not returning waters which it has diverted from Lake Michigan, but is returning it down the Desplaines River. That raises quite an interesting question as to whether the water they turn down the Desplaines River belongs to the riparian owner or to this Sanitary District. Then comes up another quite interesting question as to what right the Sanitary District has to be diverting water from Lake Michigan. In fact, the United States has stepped in and has enjoined the Sanitary District

from turning any water down this river. But instead of the amount that they now turn down, they want to turn down from ten to fifteen thousand cubic feet a second, and they hold a permit from the United States to turn down about between four and five thousand.

Mr. Goff. — Isn't there another complication? Hasn't the state of Illinois declared the Sanitary District channel to be a navigable stream?

Colonel Townsend. — I can give you several more. I have just got started. There are several.

Mr. Goff. — I didn't know how much you were loaded.

Colonel Townsend. — There are several more. I was just going to give these as a legal conundrum for your decision. Now, the Sanitary District has proceeded to enjoin property holders from building dams to utilize this water that has been turned down by them, claiming the right for itself. I believe the courts of Illinois have decided against them. But recently the Department of Justice of the United States has proceeded to enjoin these people on the part of the United States. Well, now, as the Sanitary District is using this water contrary to an injunction, or an injunction of the United States is restraining them, I don't quite see how the United States comes in, but that gives you another little thought. Then comes the prospect, if the United States should realize its claim, through Congress, which would be the only power that could enforce it, then who owns that water, and who owns that water-power? [*Applause.*]

The Chair. — Mr. Canfield, can you give us the benefit of your views on this subject?

Mr. George L. Canfield. — Just a word, Mr. President and gentlemen. From the standpoint of a lawyer, I was very much interested in Professor Davis' paper, for it seemed to me to outline the way in which certainty may be ultimately reached in a very perplexing class of legal questions which have arisen in the past, and are going to arise with greater frequency in the future, in regard to riparian rights and riparian boundaries, particularly along these Great Lakes. The situation here, from a lawyer's standpoint, if you please, is perplexing. You have got here on these waters what the Supreme Court of the United States has told us are high seas, and you have got half a dozen states and one foreign country bordering upon them, and you have got at least seven different sets of legal rules for determining riparian rights and riparian boundaries along them. They are not consistent. The decisions of individual states are not consis-

tent with themselves. The water is a thoroughfare that is becoming very crowded, and it will become much more crowded in the future. Over it all is the paramount right of navigation,— conserved by the National Government. Under it and along its borders are the property rights of the people that live along the littoral. They are coming into conflict. The questions are becoming more acute in the future as property rights become greater. If some method could be devised to put into actual legal effect some such method as Professor Davis has suggested, it would seem to be a most prudent and most proper step to take, in order that these rights may be defined, that these locations may be defined with precision, so that when questions come up into the courts, results may be reached with satisfaction. The legal propositions bearing on these matters are not the subject of very much dispute. Lawyers generally would agree upon them. They are thoroughly well settled. It is the application of them to particular facts that largely makes the trouble.

Here in Michigan our water rights started originally in the old French days, and continued under the theory of the civil law down until perhaps 1850. Under the civil law, which followed the old Roman law, the question of riparian rights below the water's edge was eliminated, for private property under that law stopped at the water's edge. The soil beneath the water belonged to the Government, to the king in the days when the Frenchman occupied this territory, and that title which the French king had passed to the English crown, and remained in the English crown during the period of British occupancy. And when the British crown surrendered its rights to this Government, and when Virginia ceded what rights she had acquired by right of conquest of this territory to the old confederation, that title still remained in the general Government, and riparian rights did not pass below the water's edge. Shortly after the organization of Michigan as a state, the question came before what was then the court of chancery, a case involving the River Raisin at Monroe, and the court then affirmed that old doctrine, that as far as private titles passed, they ceased at the water's edge, and below that the entire title was in the state. I think the date of the case is somewhere in the 1850's, or possible the 1860's, when the question came up again in regard to rights here on the Detroit River. The case is an interesting one because it represents a complete change from what had been the apparently settled law of the state down to that time. A man owning property on the shore opposite Belle Isle, somewhere about where

Owen Park is now, had leased it to a man engaged in the ice business, as I recollect. Another man who was engaged in towing or in the lumber business, brought down, that fall, a large raft of logs, and as the season was closed for navigation, he moored that raft somewhere, I suppose, in that sort of a bay below the water-works. Of course, the presence of that large raft of timber there prevented any marketable ice being cut that winter, and the riparian owner brought a suit in trespass for his damages. The Supreme Court in that case announced very positively the rule that the riparian owner owned right out to the thread of the stream between the American shore and Belle Isle, that he owned the land below the water, and was entitled to maintain his action of trespass against the owner of the raft. The rule announced in that decision has been, I think, adhered to consistently ever since in respect of rivers within the state of Michigan. Considerable authority, perhaps, could be produced that the rule was unnecessary to the decision and is possibly a mistake; but, however that may be, it is the law in Michigan, and will be until it is changed by legislation, if at all. Following that there were several cases in which they applied a similar rule to the Great Lakes, and authorities can be found for the proposition that the title of the riparian owner along Lake Huron, for example, extends indefinitely out to the international boundary there, although in later decisions the court appreciated the difficulties into which they were getting on that theory, and the rule is understood to be settled now that, on the Great Lakes, the title of the owner stops at the water's edge, and that the soil beneath the water in the Great Lakes belongs to the state.

Over on the other side of the boundary line, in Canadian waters, the courts have held that private titles do not pass beyond the water's edge, although I understand they have a form of grant there of leasing what they call water rights or water lots, that extend up to what they call the twelve-foot channel. But in applying that rule here in Michigan, the rule that I have indicated, which the decisions of the Supreme Court have laid down, you will see the difficulty that perhaps one might get into. There is one rule for the rivers, another rule for the lakes. The rivers themselves are straits, perhaps international in their character, and if the rules of general law are applied, the proposition is that the same law which applies to the large bodies of water applies to the straits which connect them. But, taking it as it is, and just to illustrate the difficulties of the situation at present, Mr. Perry referred to questions arising on Lake St. Clair. Now, the question then

would come up, is Lake St. Clair one of the Great Lakes or not? The only court that has had occasion to pass on the question told us some years ago that they did not think Lake St. Clair was one of the Great Lakes. They said that they thought it was a mere expansion of the river which had its source up in Lake Huron and its mouth at Lake Erie, comparing it to the Tappan Zee in the Hudson, or Lake St. Peter in the St. Lawrence, and rather intimated, although they did not decide, that the rules applying to rivers should apply to Lake St. Clair. If we assume, for the sake of the argument, that that intimation of the court would be followed in future litigation regarding Lake St. Clair, you might have a man that owns land along the shore, owning out to a considerable distance, for the boundary line, although it is not at present very well defined, cuts across somewhere at the upper end of Peche Island and perhaps half way up the cut at Lake St. Clair, leaving a very large area of water or submerged land to belong to riparian proprietors perhaps, to the westerly. In New York, along the Niagara River, the rule prevails that originally applied here in Michigan, as we understand. The rule is the same rule, we understand, that applies in Illinois, at least along Lake Michigan. It is somewhat different in Minnesota, although all these conflicting rules depend upon local application of principles that are fairly well settled, perhaps the one main original test being the question of the navigability of the waters.

As I said, these lakes, and still more the rivers here, are becoming very crowded. The property interests are increasing upon them very fast, and will continue so to do. Conflicts of title are bound to come. Rules as they at first exist, as laid down by the courts, have only been applied to special cases. They do not afford any fairly satisfactory lines of procedure for the future. Take for example the rules that Mr. Perry mentioned for projecting the lines of the riparian proprietors out. How, in the case of islands along these rivers, are those lines to be projected? Do they go laterally? Do they go longitudinally, up and down? What are the elements of the title of the riparian owner? Those are not defined. It seemed to me, in listening to Professor Davis's paper, that if legislation, if you please, could be obtained, which would define these boundaries and provide some method for their survey and registration, it would be of great value to the public, and tend to make property rights more definite and certain than they now are. [*Applause.*]

The Chair. — Gentleman, are there any further remarks

or questions that any of our members would like to ask Professor Davis?

PROFESSOR DAVIS. — Mr. President, I think there has been a great deal of undeserved attention paid to an old crank of a surveyor, and while I rise to express my thanks, I also wish to make the confession that I have succeeded in my original occult intention of getting some good legal advice without paying for it. [*Laughter and applause.*]

A MEMBER. — There is a question which just came to my mind with respect to the legal side of riparian rights that was brought to my mind by certain conditions that have arisen in the office of the lighthouse engineers in this district. There, of course, all properties are bordering on the Great Lakes or connecting rivers, and there have been times when it was necessary to erect aids to navigation in the water itself as submarine sites, as they call them. Originally, at least up to the time of about 1870, it was necessary to procure a grant from the governor of the state to occupy a submarine site. On the theory stated by the legal gentlemen here to-night, that all rights on the Great Lakes, all riparian rights, have rested with the state government, the United States Government had no such rights. The impression is now that since the time of about 1870 — I don't remember the exact date — the United States has supreme jurisdiction over all the Great Lakes submarine property. I know at least that no grants have been made by the governors of the state of Michigan to lighthouse establishments in a long term of years, and that these submarine sites have been repeatedly occupied by structures built by that department. There is an uncertainty that I would like to have cleared up.

COLONEL TOWNSEND.—For the purpose of navigation, the United States Government is supreme. For any purposes of navigation it may take possession of anything on the water, but only for the purpose of navigation. A lighthouse would be for the purpose of navigation.

THE CHAIR. — Here is a fine opportunity for getting more good legal advice, and other things, for nothing. We don't strike a soft snap like this every day.

MR. DOW. — I don't want to question Colonel Townsend, but I think he made his statement a little broader than he meant to make it. I think the United States has an undoubted right to take possession of any property under the water for use in the regulation of navigation, for aids to navigation, but not of improvements which may be upon that property. I think the

colonel's statement was a little broader than he meant to make it.

Colonel Townsend. — For no purpose except navigation. I meant to confine it to navigation purposes.

Mr. Dow. — The point I make is that I think he does not want to say that it has the power to take any land under the water, because that would carry with it improvements existing upon that land. There might not be compensation for the land, but there would be for the improvements.

Colonel Townsend. — Only for the purpose of navigation. It is purely for purposes of navigation that the Government can utilize the land under the water.

Mr. Dow. — Well, I will leave it to the colonel. It will end in the courts some day.

A Member. — During the last few years there has been considerable trouble around the St. Clair flats. A large amount of that property is under litigation. Couldn't we get some information along that line? I have a personal interest in the property.

The Chair. — Well, all of us more or less have an eye that way. I don't know whether we can get anybody to volunteer to tell us anything about the St. Clair flats property or not.

Mr. McMath. — A few years ago I took a canoe trip down the Clinton River, which is a small stream, averaging about twenty to twenty-five feet wide, but quite nicely navigable for a canoe. I found repeatedly that the farmers had extended their fences clear across the stream. I have often wondered since whether, if a man owned both sides of the stream, a small stream like that, and yet navigable for small boats or canoes, if he really had a right to put a fence clear across.

The Chair. — I think that comes back to Mr. Goff here.

Mr. Goff. — We generally, on those questions where they assume such a personal aspect, demand something in advance. [*Laughter.*]

Mr. McMath. — I am only asking now for the sake of all canoeists. I may say, in many of those cases I cut the fence.

Mr. Goff. — You never have had to suffer any damage for cutting the fence?

Mr. McMath. — They never got me.

Mr. Goff. — Of course, the lowest form of navigability is for logs and such things as that, and floatage of canoes. That is a very low form of navigability. It is nevertheless recognized as a sort of navigability, and consequently that must be said to be a navigable stream, for the purposes for which you use it, and

consequently, if they built a fence clear across, it would be interfering with a very low form of navigation. Consequently, I should think that they would not have the right to do that. They would not have the right to build a fence clear across preventing my going up and down with the canoe. That would be my idea about it now.

PROFESSOR DAVIS. — Aren't you mistaken about that? [*Laughter.*]

MR. GOFF. — I thought I would get him stirred up after a while.

PROFESSOR DAVIS. — Does not a deep draft vessel navigate lower than a log?

MR. GOFF. — That is not what I am talking about: low in degree, not in depth of water. I should get into as much difficulty as the man who put the inscription on the tombstone of Mary Brown. Her name was Brown, but when they came to have the inscription made, the man that had to compose it was considerably worried. Finally he made up this:

> "The last remains of Mary Jones
> Lie buried underneath these stones.
> Her name was Brown, the name of Jones
> Is used because it rhymes with stones."

THE CHAIR. — I am sure we are very much indebted to our fellow-member, Professor Davis, and the gentlemen of the legal profession who kindly came to be with us. This border line, which is neither our profession nor apparently theirs, because they shove a lot of it off on to us, is really very entertaining indeed. I know we will all go away with some thoughts of one sort or another, and I wish we had thought of them a little bit sooner, and had a chance to get some more of this legal advice. On behalf of the society, it gives me great pleasure to thank our speakers this evening, and hope that we may be able to have them again with us on some similar occasion. The meeting will now stand adjourned.

GARDNER S. WILLIAMS (*by letter*). — Limit of time prevents the contribution of such a discussion as this paper merits, but it will certainly be interesting to recall the language of the Supreme Court of the United States in the case of Iowa *v.* Illinois, 147 U. S. 1. In this case, Iowa contended that the boundary, being the middle of the Mississippi River, was the middle between banks, while Illinois claimed it to be the middle of the main channel. The court says, "We therefore hold . . . that the

true line in navigable rivers between states of the Union, which separate the jurisdiction of one from the other, is the middle of the main channel of the river. Thus the jurisdiction of each state extends to the thread of the stream, that is, to the mid-channel, and, if there be several channels, to the middle of the principal one, or rather the one usually followed."

The above decision is based upon the fundamental idea of the right to navigate and to land on the shores, the first of which rights is open to all and the second belongs to the riparian. As the first recognized use made of the water of rivers seems to have been that of navigation, all water-right law has become tinctured with the requirements of navigation, which fact accounts for some of its peculiarities.

The writer indorses the plea for a more accurate as well as for a more rational method of establishing riparian boundaries, so strongly presented by the author, but is not sure that the line of steepest descent will always meet the case. He does, however, unreservedly support the proposition that the engineer employed to prepare evidence for the use of a court must be untrammeled by restrictions as to the character or extent of his findings.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1910, for publication in a subsequent number of the Journal.]

DISCUSSION OF PAPER, "EAST BOSTON DEEP-WATER TERMINAL OF THE BOSTON & ALBANY RAILROAD."

(VOLUME XLV, PAGE 18, JULY, 1910.)

MR. H. G. PERRING. — I have read with interest Mr. Morphy's paper. I am particularly interested in his statement of the use of plaster board in the floors and partitions of this important work.

The plaster board referred to, known as Sackett plaster board, is a built-up combination of alternate layers of felt paper and plaster, four layers of paper and three of plaster being used; the outside surface is thus paper to which gypsum plaster (hard plaster) will adhere perfectly.

The gypsinite studding is a composition of plaster and wood fiber poured in a liquid state around two strips of wood which afford nailing facilities.

It is interesting to note that these two fireproofing materials are made from calcined gypsum or plaster of Paris. Plaster of Paris has been used with excellent results in Europe for many years as a fireproofing material, but its full value has never been recognized by either the general public or by technical men in the United States.

Plaster is highly efficient as a fireproofing material in many forms, such as plaster blocks, plaster boards, gypsinite studding and as a plastering. It is light in weight and inexpensive.

Despite popular prejudice and lack of general public information, plaster has been used for fireproofing in these large structures, largely on the recommendation made by the Associated Factory Mutual Fire Insurance Companies' experts.

It is sincerely to be hoped that the test of this construction in fire is not to happen, but my investigations of plaster lead me to believe that if the test does come, plaster will not be found wanting.

ASSOCIATION
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THE DEEP WATERWAY FROM ST. LOUIS TO CAIRO: A REVIEW OF SEVEN PROPOSED PLANS FOR SECURING A FOURTEEN-FOOT WATERWAY.

BY J. W. WOERMANN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 5, 1910.]

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UNDER the provisions of the river and harbor act of March 2, 1907, the Secretary of War appointed a board of engineers to investigate the question of a fourteen-foot waterway from St. Louis to the Gulf of Mexico. The board consisted of Col. W. H. Bixby, Lieut.-Col. C. McD. Townsend, Lieut.-Col. J. G. Warren, Mr. Henry B. Richardson and Mr. Homer P. Ritter.

Physical Characteristics.

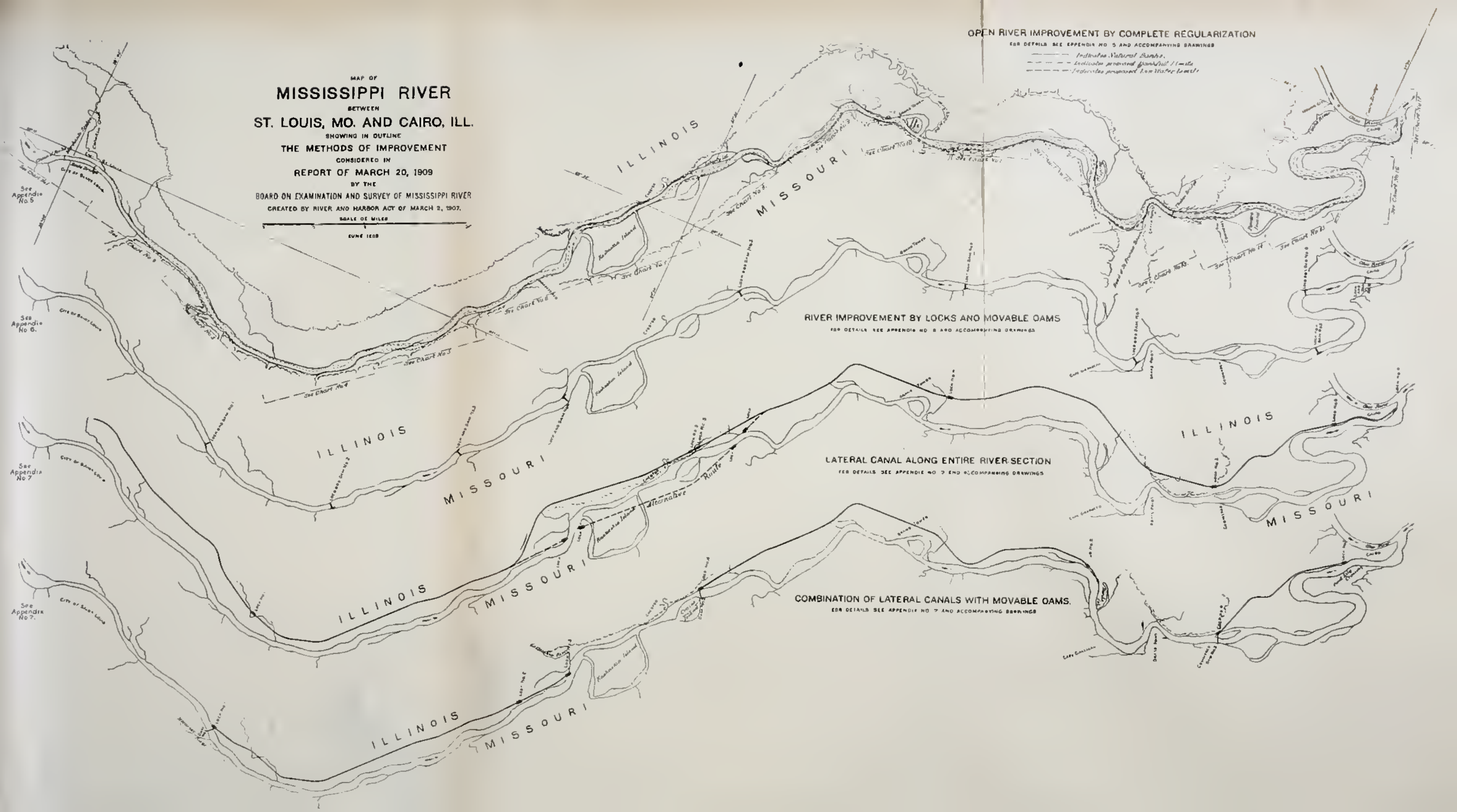
The section of the Mississippi River extending from St. Louis to Cairo, which is sometimes called the "Middle Mississippi," is recognized as the most difficult portion of the proposed waterway from Chicago to the Gulf. The entrance of the Missouri River near the upper end of this reach produces a stream which is radically different from the Upper Mississippi, and one which must be improved by different methods. The entrance of the Ohio River at the lower end of this section produces another change in character and simplifies the problem of improvement below Cairo.

Of the great basins constituting the Mississippi valley, the Missouri is by far the largest, amounting to forty-three per cent of the entire valley. The greater portion of the Missouri valley is a comparatively *dry* region; the Upper Mississippi valley has a moderate rainfall; while the Ohio valley has a heavy precipitation. The Ohio basin constitutes only sixteen per cent. of the entire valley, but it contributes about three times as much water as the Missouri. As a silt-bearer, however, the Missouri exceeds the Upper Mississippi and all of the other tributaries combined.

From St. Louis to Grays Point, a distance of 137 miles, the river flows through an alluvial valley having an average width of about 5 miles. Between Grays Point and Commerce the river is closely confined between the two bluffs, which are about a mile apart. Below Commerce the valley widens out into the St. Francis basin on the right and the Ohio valley on the left.

The channel distance from St. Louis to the mouth of the Ohio River at a zero stage on the St. Louis gage is 182.5 miles. The distance in a straight line is 125 miles. At a zero stage the width varies from 650 ft. to 4 000 ft. The total fall, at the zero stage, is 107.3 ft., an average fall per mile of 0.59 ft., or approximately 7 in. This slope is not uniform, however, but varies from 0.3 ft. in the vicinity of St. Louis to 0.9 ft. per mile near Cairo.

At St. Louis the range in stage from the extreme low water of January, 1900, to the flood level of June, 1844, was about 44 ft. The corresponding volumes of discharge were approximately 35 000 and 1 250 000 cu. ft. per sec. Just below Cairo the range between the extreme low water of January, 1900, and the flood stage of February, 1883, was about 52 ft. The corresponding volumes of discharge were approximately 70 000 and 1 600 000 cu. ft. per sec. The *mean* discharge of the Mississippi at Grafton (just below the mouth of the Illinois River)


MAP OF
MISSISSIPPI RIVER
BETWEEN
ST. LOUIS, MO. AND CAIRO, ILL.
SHOWING IN OUTLINE
THE METHODS OF IMPROVEMENT
CONSIDERED IN
REPORT OF MARCH 20, 1909
BY THE
BOARD ON EXAMINATION AND SURVEY OF MISSISSIPPI RIVER
CREATED BY RIVER AND HARBOR ACT OF MARCH 2, 1907.
SCALE OF MILES
OPEN RIVER IMPROVEMENT BY COMPLETE REGULARIZATION
FOR DETAILS SEE APPENDIX NO. 5 AND ACCOMPANYING DRAWINGS
RIVER IMPROVEMENT BY LOCKS AND MOVABLE DAMS
LATERAL CANAL ALONG ENTIRE RIVER SECTION
COMBINATION OF LATERAL CANALS WITH MOVABLE DAMS.
See Appendix No 5
See Appendix No 6.
See Appendix No 7
See Appendix No 7.
ILLINOIS
MISSOURI
Kaskaskia Island
Alternative Route

is 100 000 cu. ft. per sec.; that of the Missouri River just above its mouth is 85 000; that of the combined rivers at St. Louis amounts to 185 000 cu. ft. per sec.

The depth to bedrock varies from 50 to 100 ft. below low water, except between Thebes and Commerce, where for a distance of 5 miles it varies from 20 to 50 ft. below low water.

The Mississippi from St. Louis to the Gulf is the most unstable of all the navigable rivers in the world. The extent of its caving banks and shifting bottom are not realized by the engineering profession at large, much less by the general public.

Caving banks are the result of the erosion of the river bed below the water surface, thus undermining the upper portion, which presently sloughs off into the river. During erosion a small part of the soil is actually dissolved by the water and remains in solution; a large part (the lighter portion) is taken up as sediment in suspension, while the remainder, consisting of sand and gravel, is rolled along on the river bed.

Erosion is most active after the spring or summer flood, when a falling river has receded within its natural channel leaving its saturated banks unable to stand unsupported. An eroding bank will frequently cut back 500 ft. in three months. A study of the topography indicates that in many places the cutting back in long periods has amounted to five or six miles.

Where the river is very tortuous the peninsula, or neck of land between two large bends, is usually attacked from both sides and if left alone is eventually cut through, — forming a "cut-off." As this disturbs the regimen of the river for many miles above and below the cut-off, it is always prevented when the funds on hand will provide for proper bank revetment. If not prevented, the resulting derangement may extend over a total distance of twenty-five miles, and it may require twenty or twenty-five years before this reach becomes as stable as it was before the cut-off took place.

The most interesting feature to the student, and the most troublesome to the navigator, is its shifting bars of sand and silt. These not only move horizontally, but also rise and fall with the stage of the river, and determine the depth of the navigable channel. Usually they do not lie in a line at right angles to the bank, but extend diagonally across the river for a distance amounting to two or three times the width of the river. In this way the deep water in the upper pool extends downstream past the head of the next pool, and the water in passing from one pool into the next passes over this bar or natural weir in a com-

paratively thin sheet of water. Deep water is always found in the bends. These bars are the natural stream regulators, building out from the convex banks, and incidentally aiding in the erosion of the concave banks.

Rise and fall in the water surface is accompanied by rise and fall in the bars. Repeated measurements show that the available depth across a bar increases only about one-half foot for every foot in the rise of the water surface. In other words, while a stage of 4 ft. on the St. Louis gage furnishes a depth of about 5.5 ft. on the limiting bars, a rise of 10 ft. will not give a total depth of 15.5 ft., but only about 10 ft.

If the river falls 0.2 or 0.3 ft. per day the bars will erode at the same time and maintain a good channel. When the river falls rapidly, however, the result is most disastrous, as the bars are all high and it takes a week or more for the current to cut a channel through them.

Previous to improvement, the depth over the worst bars at extreme low water was 3.5 to 4.0 ft. The present depths at low water vary from 5 to 8 ft., according to the amount of improvement which has been maintained. With the assistance of hydraulic dredges, however, an 8-ft. depth has been maintained for many years during the navigation season, excepting only an occasional interval of a few days following a rapid fall in stage, while the dredges were cutting new channels through the troublesome bars. The depths in the pools between the bars vary from 20 to 50 ft. at low water.

Present Project for Improvement.

The project now in force was adopted in 1881 and is intended to secure a minimum depth of 8 ft. at "standard low water," which is 4.0 ft. on the St. Louis gage. To secure this depth it has been the plan to confine the flow of the river to a width of approximately 2 500 ft. up to a bank-full stage. In other words, the permeable pile dikes or hurdles have been driven so that their tops correspond to a stage of about 25 ft. on the St. Louis gage.

At first, willows were placed horizontally between the two rows of piling, but it was discovered that each hurdle soon collected enough driftwood to answer this purpose, so that "wattling," as it was called, was discontinued.

Each hurdle, by checking the current, causes a deposit to take place on the downstream side, creating a bar which is gradually built up high enough to sustain a growth of willows. The

Fig. 5. Pile Dike or Hurdle opposite St. Louis, showing Collection of Drift on Upstream Side.

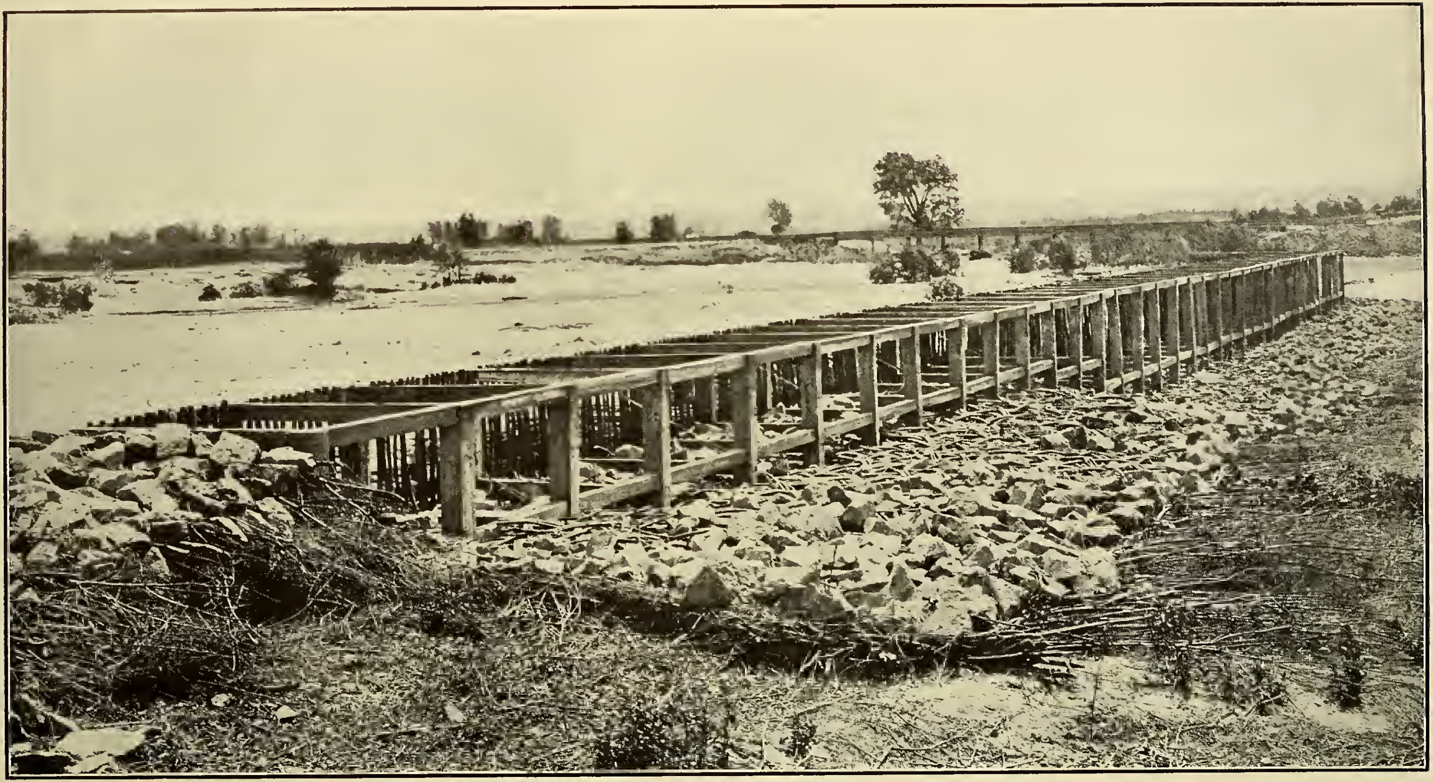


Fig. 7. New Type of Hurdle recently adopted on the Missouri River; Two-Row Concrete Dike constructed with Concrete Piles and Concrete Braces.

project also provides for the revetment of the banks, both new and old, wherever necessary to secure permanency.

A large amount of successful work was done under this project, but in 1896 the construction and operation of hydraulic dredges was inaugurated on this section, and from 1896 to 1910 the appropriations were greatly reduced, and, by order of Congress, were utilized almost entirely in dredging. The width of the dredged channel has been limited to 200 ft.

The total amount of money which has been appropriated for all purposes from the mouth of the Missouri River to Cairo is approximately $12 780 000.

Fourteen-Foot Projects.

In its consideration of a 14-ft. waterway the board investigated the following methods of obtaining and maintaining such a channel.

1. Dredging alone.
2. Complete regulation.
3. Movable dams and locks.
4. Fixed dam and locks.
5. Lateral canals.
6. Reservoirs.
7. Combination of methods.

1. By Dredging Alone.

(Abstracted from report of Assistant Engineer W. S. Mitchell.)

A natural depth of 14 ft. over the bars occurs only during the annual high-water stages, which usually occur between the latter part of April and the early part of July, a period of about two and a half months. During this period artificial aid for securing a 14-ft. channel is usually unnecessary.

Navigation is suspended intermittently on account of ice during December, January and February, the aggregate period being from one to one and one-half months.

During the remainder of the year, February to April, and July to December, the dredging plant would have to be in commission and at work as much of the time as it might be needed.

The channels which may be dredged across the bars during the fall will, in a large measure, become obliterated by ice gorges during the winter months and during the short spring season a large part of this work would have to be done over.

The greater part of the year's work, however, would be done during the long low-water period beginning in July and terminating with the appearance of ice in December, a period of about five months.

The two main sources of the sediment which enters this reach are the Missouri River, and the Mississippi River's own caving banks. From the former it is estimated that between 250 000 000 and 400 000 000 cu. yd. are received annually, and from the latter, one fifth to one fourth as much.

Measurements of the amount of bank erosion between St. Louis and Cairo by ten-year periods show *annual* losses as follows:

1879–1889	921 acres	64 000 000 cu. yd.
1889–1899	633 acres	48 000 000 cu. yd.
1899–1907	676 acres	49 500 000 cu. yd.

The decrease in caving in the last two periods is credited to the extension of bank-protection works.

On account of the influence of duration of stage upon the channel depths, estimates of the amount of excavation necessary to secure a 14-ft. channel cannot be exact. According to the soundings taken during the recent survey, which are thought to represent typical conditions, excavation would be required at about seventy localities between St. Louis and Cairo, the total length of excavated channel being about 61 miles, and the total amount of excavation about 35 000 000 cu. yd. These figures are based upon a zero stage on the St. Louis gage.

The project now in force calls for a depth of 8 ft. and a channel width of 200 ft. At a zero stage this requires dredging at not more than 40 localities, and the length of excavated channel is about 19 miles. The total amount of excavation is only 2 300 000 cu. yd.

Using 35 000 000 cu. yd. as the maximum amount of dredging which would be required in any low-water period, and two months as the shortest time for its accomplishment, the dredging plant must have a capacity of 17 500 000 cu. yd. per month.

The cost of such a plant, including the attendant vessels, shops, etc., based upon the cost of similar plant now in use on the Mississippi River, is as follows:

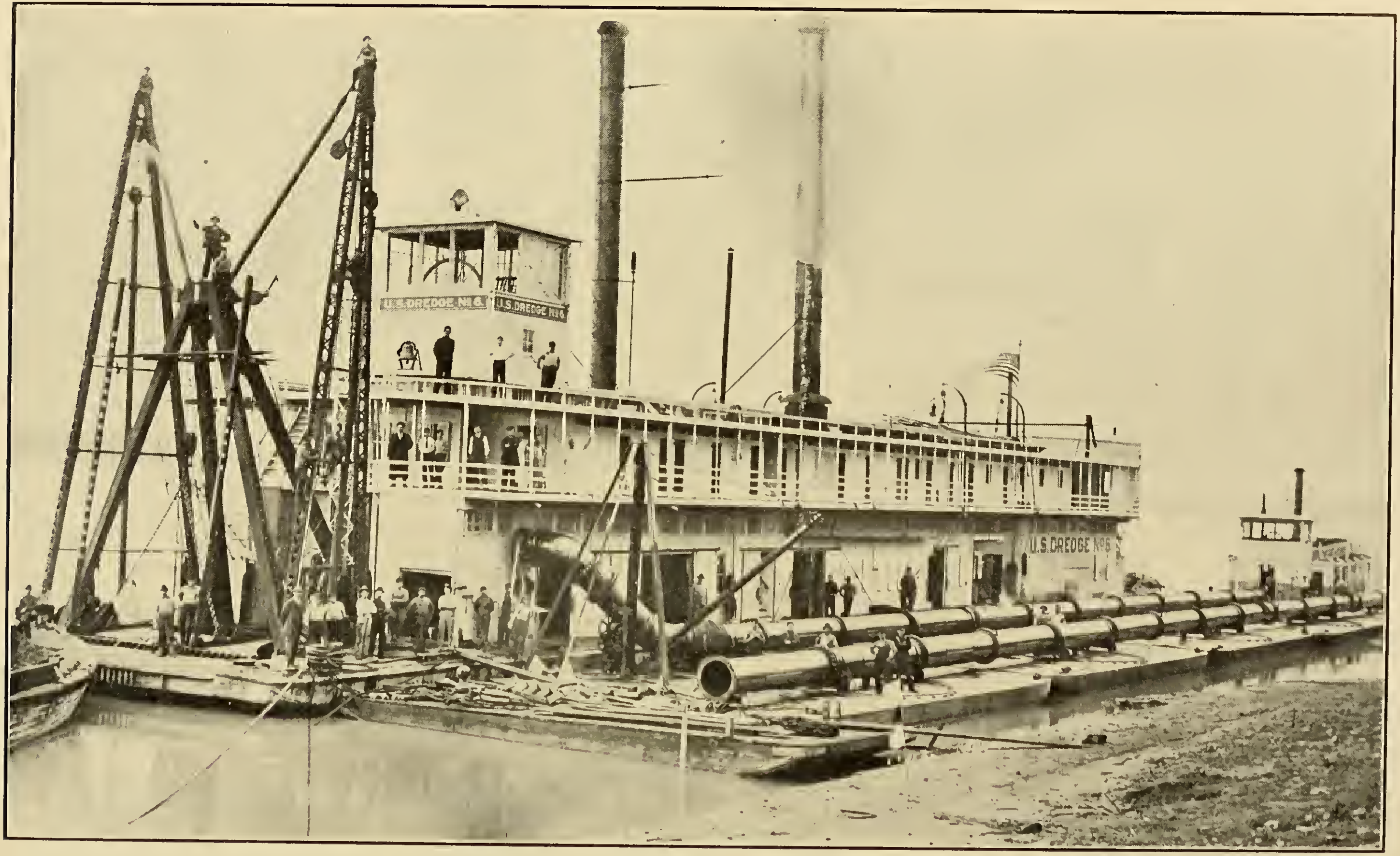


Fig. 1. One of the Self-Propelling Dredges in Use between St. Louis and Cairo; Diameter of Pipe, 32 inches; Width of Suction Head, 32 Feet.

Estimate of Cost of Dredging Plant.

20 self-propelling steel hull dredges, Harrod type, at $250 000 each,	$5 000 000
40 wooden hull fuel barges, 500 tons each, at $6 000	240 000
3 steel hull towboats, " King " type, with sufficient power to tow a disabled dredging plant, 2 of the steamers to be used ordinarily for distribution of fuel and supplies, and 1 for channel examination and inspection, at $75 000 each	225 000
4 steel hull survey boats, or tenders, at $20 000 each	80 000
1 engineer depot, for supplies and repairs, with store buildings, shops, forges, etc.	50 000
1 marine ways at engineer depot	50 000
Tools and appliances, office equipment, surveying instruments, etc.	25 000
Contingencies and miscellaneous	330 000
Total	$6 000 000

To assemble this large plant will probably require at least five years, and possibly much longer, on account of the small number of boat yards on the Mississippi and its tributaries.

The following estimate of operating expenses is based upon the cost of operating dredges between St. Louis and Cairo during the past ten years, with charges for fuel, deterioration, etc., correspondingly increased for the larger dredges contemplated.

Operating Expenses.

20 dredges in commission and operation during nine months of the year at $10 000 per month for each dredge	$1 800 000
20 dredges laid up and undergoing repairs, etc., during three months of the year at $2 000 per month for each dredge	120 000
Administration, contingencies, etc.	80 000
Total	$2 000 000

This charge is equivalent to an average annual expenditure of $100 000 per dredge, and includes operating expenses of the subsidiary vessels, engineer depot, surveying parties, etc.

2. Complete Regulation.

(Abstracted from report of Assistant Engineer Wm. M. Penniman.)

A system of complete regulation would embrace three forms of permanent construction, as follows.

I. Side-Contraction. The building of new banks to the height of the bank-full stage on the projected alignment and slope, thus securing the contraction of the stream necessary to produce the required depth; to be accomplished by wing-dams, permeable or solid.

II. Bank-Protection. The protection of all concave banks in alluvium, whether natural or created by induced accretion; also, when required to preserve alignment, of some sections of straight and slightly convex banks; to be accomplished either by low training walls or by revetments.

III. Stream-Bed Control. The regulation of the entire bed of the stream, by fixation of the crests of controlling bars, whether these bars be natural or artificial, thereby equalizing the fall and preserving a comparatively uniform slope; to be accomplished by sill dams or cross-weirs, thus *maintaining* the desired *depth* of channel when obtained by the works of side-contraction and bank-protection.

Hydraulic dredging is proposed as an auxiliary process to assist the natural forces and hasten the development of the proposed channel. Not only during construction, but after completion of the permanent works, a small amount of dredging will be necessary to hasten the removal of temporary shoals caused by a fall so rapid that even a completely improved river will be unable to correct itself simultaneously with decrease in stage.

Briefly stated, this project for open river improvement by a regulated channel with sill-dams or cross-weirs is intended to equalize and render more uniform the water-prism at all points throughout the length to be improved, and at all stages below the bank-full stage; to reorganize, but not radically to alter, the bed of the stream, transforming the bad passages into good passages by substituting for the natural controlling bars, artificial bars or weirs, which shall maintain a fairly uniform slope and constant gage height for a given volume of discharge, and to smooth out the present great irregularities of the stream, both as to the varying width and depth, in such way as to produce and maintain at low water a practicable channel with a navigable depth of 14 ft. The places where too great width and insufficient depth now exist will be replaced by a regulated channel of the proper width to produce the requisite depth at the present available low-water discharge and without material change in the elevation of any stage.

The gorge between Grays Point and Commerce exemplifies the effect of natural conditions similar to those that should be produced by artificial control; for seven miles the river is confined between stable banks, the low-water and the bank-full widths compare favorably with corresponding mean widths for the district, and the slope is only slightly less than the mean slope; at certain places the bottom is fixed, or practically so,

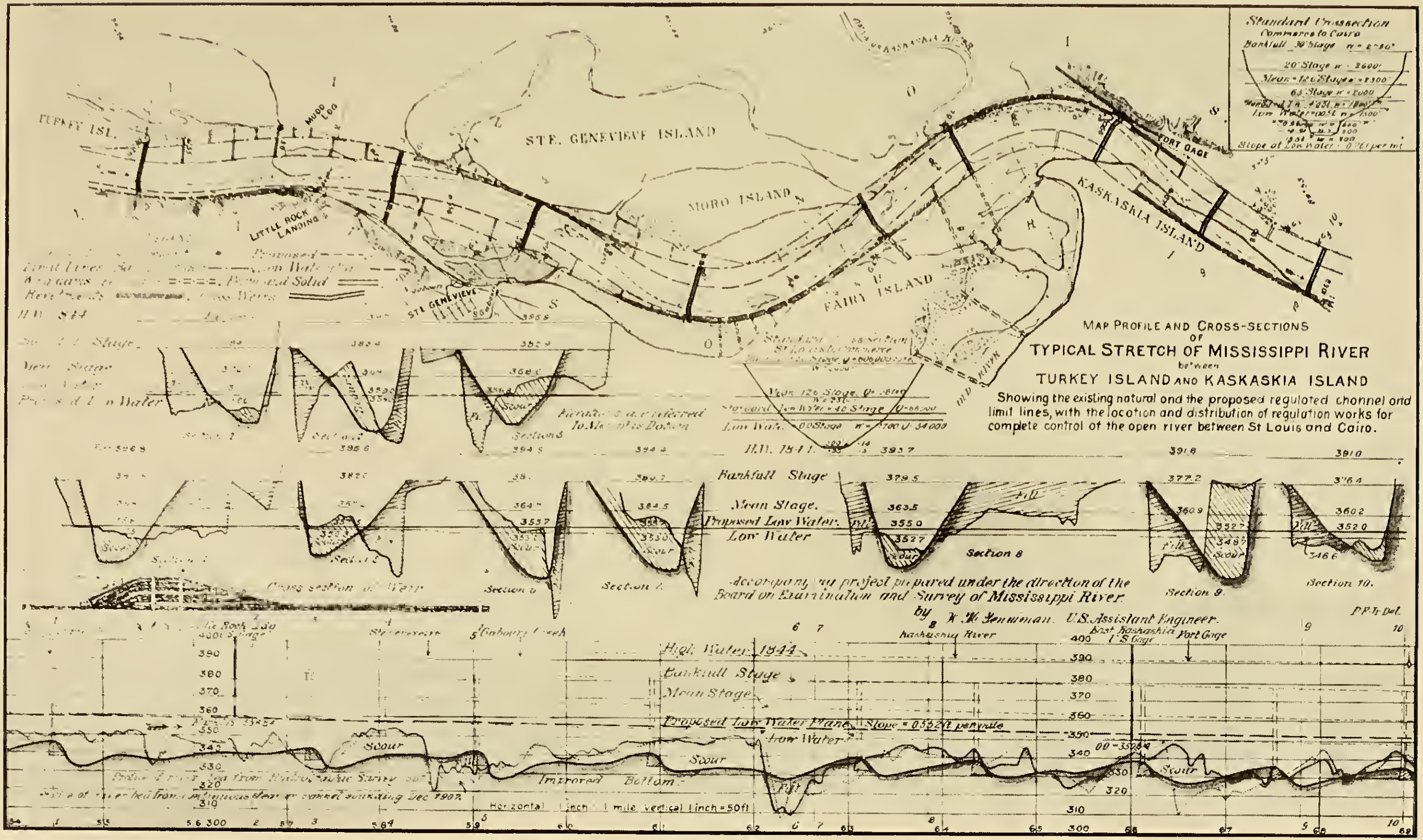

MAP PROFILE AND CROSS-SECTIONS
OF
TYPICAL STRETCH OF MISSISSIPPI RIVER
between
TURKEY ISLAND AND KASKASKIA ISLAND
Showing the existing natural and the proposed regulated channel and limit lines, with the location and distribution of regulation works for complete control of the open river between St Louis and Cairo.
Standard Crossection
Commerce to Cairo
TURKEY ISL.
MUDD LOG
LITTLE ROCK LANDING
STE. GENEVIEVE ISLAND
STE GENEVIEVE
MORO ISLAND
FAIRY ISLAND
KASKASKIA ISLAND
FORT GAGE
OLD RIVER
Bankfull Stage
Mean Stage.
Proposed Low Water.
Low Water
Section 8
Section 9.
Section 10.
Accompanying project prepared under the direction of the Board on Examination and Survey of Mississippi River
by F. W. Lenneman. U.S. Assistant Engineer.
High Water 1844
Bankfull Stage
Mean Stage
Proposed Low Water Plane
Low Water
Scour
Fill
Improved Bottom
Horizontal 1 inch = 1 mile vertical 1 inch = 50ft
Kaskaskia River
East Kaskaskia U.S. Gage
Fort Gage
P.P. Jr. Del.

Fig. 6.

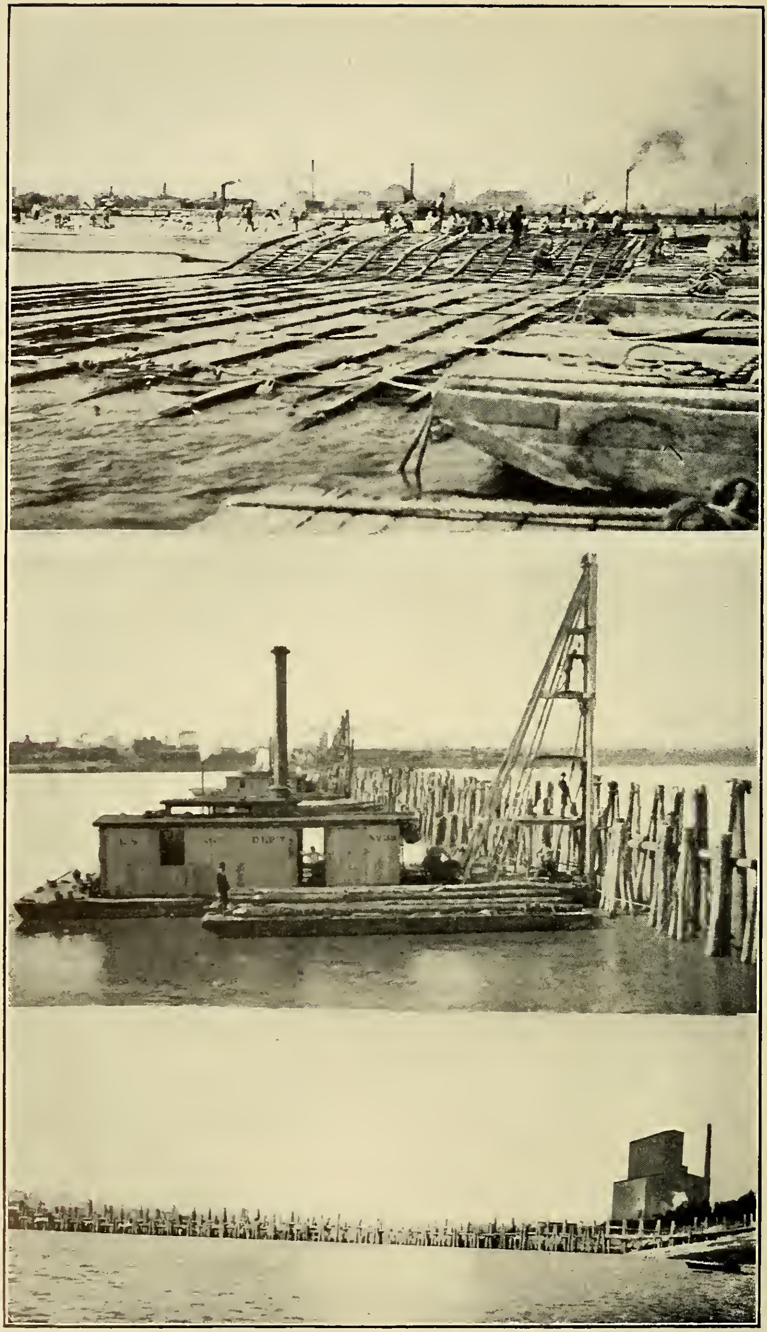


Fig. 2. Hurdles opposite St. Louis, showing:

1. Construction of Lumber Mattress for Foundation.
2. Piledrivers at Work.
3. Hurdle completed, looking upstream.

resulting in a non-changing cross-section, and except for isolated bowlders and reefs, the required width and depth are found. Permanent navigable depths exist not only throughout this reach, but extend for three to four miles above and below.

It is proposed to create an essentially parallel condition by means of complete regulation wherever the cross-section varies from the one required to maintain a navigable depth of 14 ft.

Widths for low-water, bank-full and intermediate characteristic stages have been determined from the conditions of slope and discharge, by observing the widths assumed by the natural bed at various stages and at controlling sections, and from actual known results in the district from the use of side-contraction works. A large number of cross-sections of the river-bed, especially in those reaches where the local slope approximates the mean slope, for the entire river section under consideration, furnished valuable data in deducing the mean uniform widths. For the reach from St. Louis to Commerce, the widths tentatively adopted for the low-water and bank-full stages are 1 700 and 3 000 ft., respectively; for the reach from Commerce to Cairo, with its steeper slope, they are 1 500 ft. and 2 750 ft. In St. Louis harbor these widths have already been fixed by the Secretary of War at 1 500 and 2 000 ft. The bottom width adopted is 500 ft. throughout the district.

The proposed alignment reduces the number of crossings from 56 to 34, an additional argument in favor of the artificial weirs as against the natural controlling bars.

The proposed channel line, limit lines, wing dams, revetments and cross-weirs depicted on the maps have been drawn for the purpose of presenting a comprehensive plan of improvement, and are not intended to indicate exactly the final location to be followed in construction. Where the proposed channel follows the bluffs there will probably be no change, but in a reach including a bend in an alluvial bank there will probably be radical changes before the improvements can be undertaken.

For producing accretion by arresting silt, building up new banks, incidentally reclaiming land, and for causing erosion and scour by concentration of water-flow, the permeable wing-dam or hurdle will be adopted. In the form that has been used on this section of the river, primarily for contracting the stream and deepening the channel, this construction consists essentially of one to three rows of piling or clumps of piling, driven on a line about normal to the currents, and to the desired stage-height, generally penetrating and holding in place a foundation mattress

of the needed dimensions. Usually the piles are placed so that they may be drawn together and fastened in clumps of three or four piles each. The slight upstream trend of the line of piling will usually cause masses of drift to be held against wind and current until such accumulations can be sunk, and will also induce a more rapid fill near the old high bank where bank-full accretions are slowest to form.

The sinking of drift with mattress and stone is a most important adjunct to the action of permeable hurdles and wing-dams, adding greatly to the permanence and effectiveness of the constructed works, increasing the rate and enhancing the solidity of the deposit.

Bank protection or revetment will generally consist of a foundation mattress of required width (about 150 ft. or less, depending upon the configuration and character of the bank to be protected), placed below the low-water line and heavily ballasted; and of a pavement of stone on the upper bank section, after being graded to a slope not steeper than two horizontal to one vertical, from the subaqueous portion of the revetment to the bank-full stage. Until a cheaper but equally effective form of construction may be devised, the mattress will be of the woven type of green saplings or sound cull lumber, which has been used in this district for many years with entire satisfaction. In mattress construction, provision should be made for a thoroughly substantial method of fastening the top poles and cross poles to the mattress proper, as on these fastenings and their durability depends the preservation of the " pockets " that hold the stone in place as distributed. Retaining the ballast in these pockets is a very important matter, because on steep banks, and especially when scour and settlement take place, much of the stone will otherwise roll off the mattress and be lost. The use of bronze in place of iron fastenings is a construction detail worthy of mention, and reinforced concrete slabs for protecting the bank slopes above the low-water line may eventually prove more effective and cheaper than stone alone.

Sill-dams or submerged cross-weirs as a means of controlling the stream depth have been in use many years, especially on European rivers. In Germany they are called " Grundschwellen." In many cases they have been resorted to for the purpose of raising the low-water plane after contraction works alone had resulted in too much scouring out of the bottom. They have not yet been used in so extensive a plan, nor on so large a scale as proposed in this project.

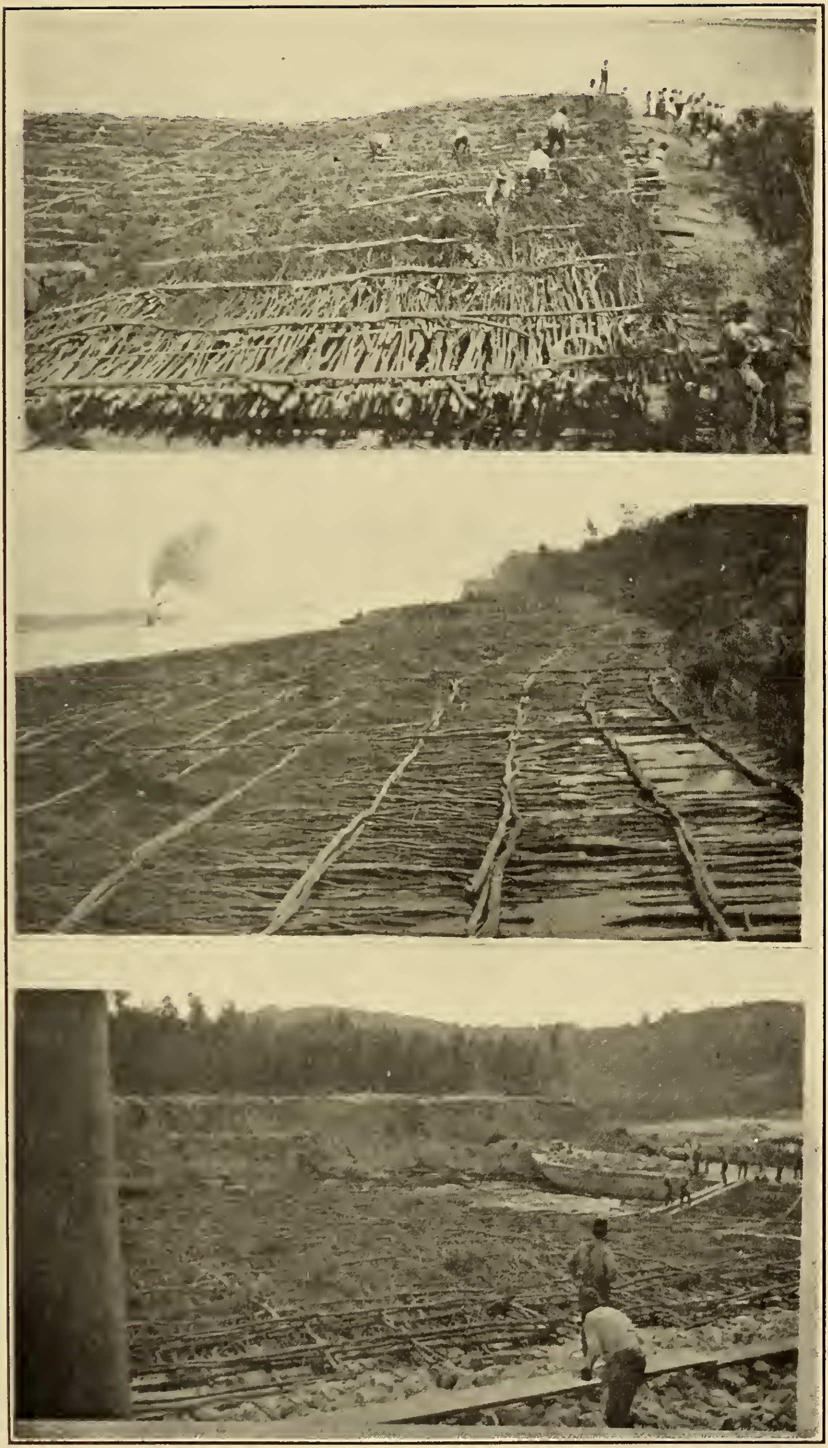


Fig. 4. Bank Revetment between St. Louis and Cairo:

1. Willows being woven into Mattress on Skids supported on Flatboats.
2. View from opposite end of Mattress; Flatboats in distance.
3. Mattress being sunk with Stone from Barges.

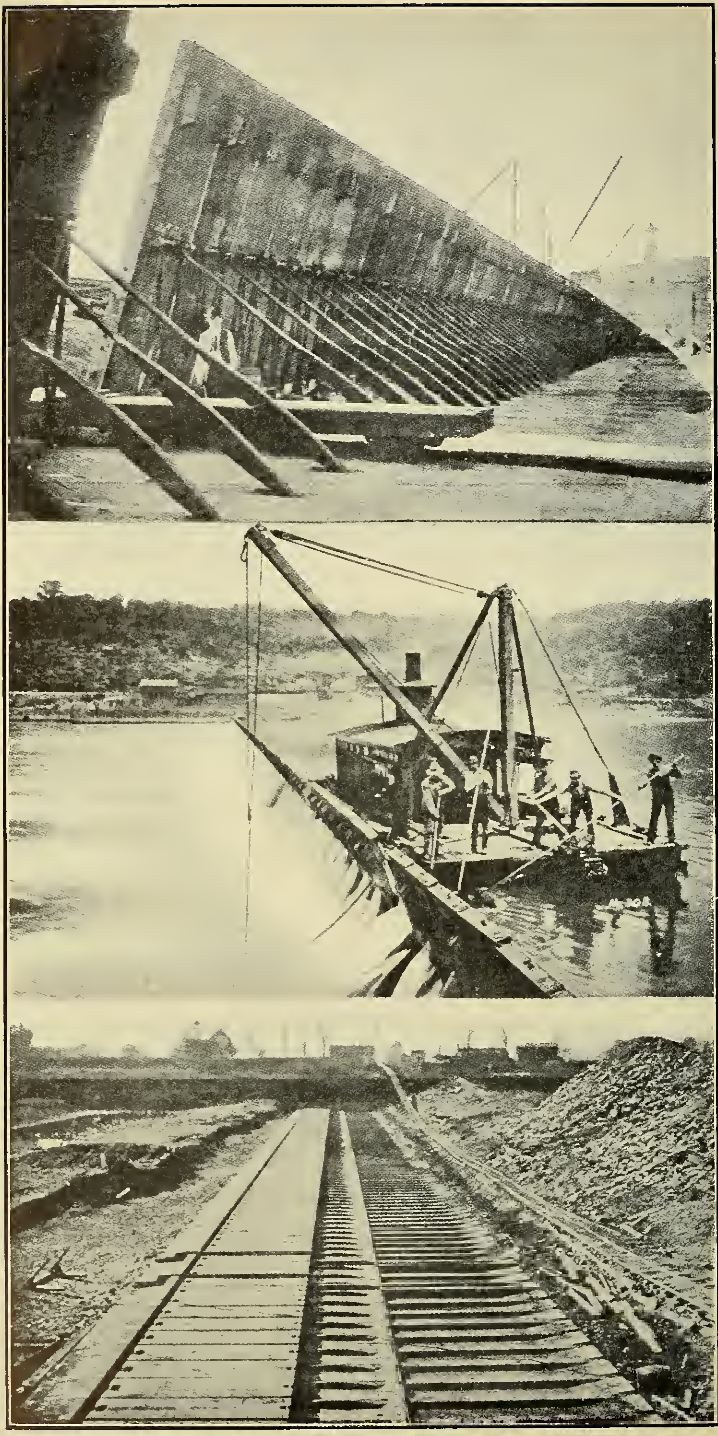


FIG. 3. CHANOINE WICKET DAM ON OHIO RIVER, SHOWING:

1. Wickets raised.
2. Derrick Boat raising Wickets.
3. Wickets down.

The number of cross-weirs necessary to produce a 14-ft. channel might exceed the total number of natural submerged dams (about 60), any one of which might have heretofore become obstructive to 8-ft. navigation. One hundred weirs should be more than adequate, and that number would allow them to be placed about one and three-quarter miles apart, the mean fall between weirs being 1.1 ft. It is believed that this spacing will effect a satisfactory improvement and at the same time preserve an almost uniform slope.

ESTIMATE OF COST OF COMPLETE REGULATION WORKS.

(187 miles by improved channel.)

	No. Lin. Ft.	Unit Cost.	Total.
Wing-dams, permeable	459 359 980	$25	$8 999 500
Wing-dams, permeable and solid	395 229 100	23	5 269 300
Revetments	71 644 134	20	12 882 680
Cross-weirs	97 278 250	60	16 695 000
Maintenance during 15 years			2 970 000
Total cost of regulation works			$46 816 480
Dredging plant and dredging during 15 years			6 400 000
Grand total			$53 216 480

After completion of the project, the maintenance of permanent works, and the maintenance of the required channel-depth, including the dredging of temporary shoals, will require an annual expenditure of less than $500 000.

3. THE SLACKWATER PROJECT, BY MOVABLE DAMS AND LOCKS.

(Abstracted from the report of Assistant Engineer J. W. Woermann.)

This is a project for securing a 14-ft. channel from St. Louis to Cairo by means of movable dams similar to those in use on the Ohio River.

Between St. Louis and Cairo there are about 40 bars or crossings where the depth is less than 8 ft. at a zero stage, and about 70 localities where the depth is less than 14 ft. These are located at irregular intervals and vary greatly in elevation and are responsible in a large measure for the variations in the lengths of the proposed pools and the lifts of the proposed locks.

In selecting the locations for the dams, the heights of the banks, width, depth and slope of the river, proximity of tributaries and other local features were taken into account. In order

that there might be ample discharging capacity over the sills, during extreme floods, no site was selected where the width was less than 3 000 ft. at the time of the recent survey.

The project as blocked out provides for a system of 10 locks and 10 dams. The 10 pools vary in length from 6.8 to 26.9 miles. The *average* length of the pools is about 18 miles. The lifts of the locks vary from 5.2 to 15.0 ft. The *average* lift for the locks at a zero stage is 9.87 ft.

In the spring or early summer, as the natural depths decreased to 14 ft., the dams would be raised as required, and as the volume of water decreased the lifts would gradually increase from zero up to the maximum heights given above.

The size of locks adopted by the previous 14-ft. waterway board for that portion of the waterway from Chicago to St. Louis was adopted by the present board, viz., 80 ft. in width and 641 ft. between hollow quoins, or a length of 600 ft. in the clear. The length over all, exclusive of wing walls, is 866 ft.

The floors and walls of the locks are of Portland cement concrete. The coping of the main portion of each lock is carried up to 24 ft. above the sill of the adjacent dam, so that it is available for service whenever the lock is required for navigation. The locks are founded on piles, which are protected from scour by sheet piling and mattress work.

Five pairs of steel mitering gates are provided for each lock, viz.: one pair of upper guard gates, one pair of upper lift gates, two pairs of lower lift gates, and one pair of lower guard gates. The lower guard gates open downstream and would be used only when it became necessary to pump out a lock for repairs.

As provided in the act of Congress under which this work was done, estimates were prepared for movable dams of the Chanoine wicket type. The movable parts of the dams are the wickets, the horses and the props. The wickets are usually made of timber, bound with steel, but may be made entirely of steel. They are 3 ft. 9 in. wide, with 3-in. spaces between them for clearance. The wickets are supported just below their centers by the horses, about which the wickets are free to swing. The horses, which are made of structural steel, are hinged to the foundation at their lower ends and to the wickets and props at their upper ends. The props are steel forgings, made very heavy at the lower end. The hurters are iron castings, fastened to the downstream part of the foundation. They have seats, which support the props when up, and grooves which guide them in their ascent and descent.

On the Ohio River it is the practice to divide the dam into

three or four sections, separated by masonry piers. The section with the lowest sill is usually placed adjacent to the lock, and is called the "navigable pass." The other sections have their sills at higher elevations, and are designated as "weirs." In raising a dam, the longest wickets, which are the most difficult to handle, are generally raised first, leaving the shorter lengths to be raised as the head on the dam is increased. In lowering a dam, the reverse order is followed. Ordinary fluctuations in stage are controlled by raising or lowering the proper number of wickets on the weirs.

The movable portion of each dam is supported upon a foundation of concrete about 40 ft. wide and 6 to 12 ft. thick. This in turn is supported upon piles 30 ft. long. Leakage under the dams is prevented by a row of triple lap sheet piling, 30 ft. in length, along the upstream edge of the concrete. Underscour on the downstream side is prevented by heavy cribwork, filled with stone, adjacent to the concrete, and a mattress of standard design beyond the cribwork.

In preparing these estimates the following unit prices were used: Portland cement concrete, $6.00 per cubic yard; structural steel, 6 cents per pound; cast-iron, 5 cents per pound; round piles in place, 40 cents per linear foot; sheet piles in place and oak timber in sills and posts, $50.00 per thousand; excavation for the locks, 50 cents per cubic yard; backfilling behind the land walls and in the cofferdam, 25 cents per cubic yard; dredging in the river bed, 15 cents per cubic yard; common labor, $2.00 per day of 8 hr.; pump engineers, $3.00 per day of 8 hr.

SUMMARY OF COST.

(Slackwater project by movable dams and locks.)

Total for ten locks	$6 486 031
8 dams at $1 350 000	10 800 000
2 dams at $1 575 000	3 150 000
Bank protection, 50 000 lin. ft. at $35	1 750 000
Levees and hurdles	300 000
Dredging in channel, 170 000 cu. yd. at $0.15	25 500
Dredging lock approaches, 150 000 cu. yd. at $0.15	22 500
Right of way, 10 lock sites, at $10 000	100 000
Contingencies, 10 per cent	2 263 403
Total	$24 897 434

During ordinary stages, say from 6 to 12 ft. on the St. Louis gage, the velocity of the current from St. Louis to Cairo will

vary from 3 to 6 ft. per second, or from 2 to 4 miles per hour, depending upon the stage, and the reach under consideration. When the dams are raised this velocity will be reduced to about one-half mile per hour in the lower portion of the pool, and about one mile per hour in the upper portion, at extreme low water. With a 6- or 7-ft. stage, the velocity will be about one mile per hour at the lower end of a pool and about one and one-half miles per hour at the upper end.

This checking of the current will no doubt result in the deposit of some of the material in suspension at the time the water passes into these pools. It must be borne in mind, however, that the dams will all be down for nearly half of the year, and it is my opinion that during this part of the year, when the velocities are greatest, most of these deposits will be scoured out and carried down the river.

In regard to the caving banks, it is my firm conviction that with the dams raised the caving of the banks will practically cease. I am drawn to this conclusion from two considerations: First, I do not believe that the banks will cave with such low velocities as have been mentioned above. Second, most of the caving occurs during a falling stage, — say from 20 ft. downward. With this system in operation, the dams would be raised at about a 20-ft. stage, and the river would not be permitted to pass through this critical period.

In view of the foregoing considerations, the annual cost of dredging under this project has been estimated at $1 000 per mile, although the actual cost may be much less.

In order to make the estimate still more liberal, $50 000 per annum has been provided for bank revetment, so that places which may show any serious tendency toward caving may be permanently protected.

During the winter when there is danger from running ice, the dams would be kept down. At times, on account of this practice, there would be less than a 14-ft. depth in the channel, but as there is so little navigation during this season of the year, this is not considered a serious objection.

Estimate of Cost of Operation and Maintenance.

10 locks and dams, at $15 000	$150 000
Dredging, 182 miles, at $1 000	182 000
Bank revetment	50 000
Total	$382 000

4. Fixed Dam and Locks.

An extensive system of borings made throughout the valley from St. Louis to Cairo developed the fact that there was only one locality where bed rock was found at a depth favorable to the economic construction of a high masonry dam.

The writer prepared a rough estimate of the cost of a project based upon the construction of a high concrete dam at Graysboro, about 9 000 ft. upstream from the Thebes Bridge, or approximately 138 miles below St. Louis.

To produce a 14-ft. channel as far up the river as St. Louis would require a dam about 117 ft. high, measured from bed-rock. The head of water on the dam would be about 73 ft. The length on the crest would be about 4 200 ft.

Such a dam, if built, should be similar in design to the famous Assouan Dam across the Nile, that is, the base of the dam should be provided with large openings throughout its full length, controlled by Stoney gates, so that the entire flood discharge could be passed *through* the dam instead of over it. In this way most of the sediment which was deposited above the dam during the low water season would be flushed out during the high water season.

If this deep pool extending from St. Louis to Graysboro were supplemented by a 14-ft. canal from the dam to Cairo the cost of such a project would be approximately as follows:

Summary of Cost.

(Slackwater project, by fixed dam and locks.)

Concrete dam, with Stoney gates	$7 000 000
Lands overflowed, 243 000 acres, at $100	24 300 000
30 towns or villages, wholly or partially flooded	4 000 000
223.5 miles railroad flooded, at $30 000	6 705 000
Other railroad property	500 000
Levee across head of St. Francis Basin, 14,000 ft. long, 50 ft. high, 4 400 000 cu. yd., at 25 cents	1 100 000
2 locks, lift 30 ft. each, at $860 000	1 720 000
Canal from high dam to Pond Lily Crossing (21.5 miles), including structures	6 660 000
Contingencies, 10 per cent	5 198 000
Total	$57 183 000

As will be noted from the estimate, the value of the property destroyed is greater than the entire cost of the slackwater project with movable dams and locks.

The cost of operation and maintenance is estimated at $250 000 per annum.

The only attractive feature of this project is its water-power possibilities. Even at extreme low water it would be possible to develop about 310 000 h.p. on the turbine shafts.

5. Lateral Canals.

(Abstracted from report of Assistant Engineer J. W. Woermann.)

The canal projects provide for a canal of the same size as the canal sections of the 14-ft. project between Chicago and St. Louis, viz., a canal trunk with bottom width of 160 ft., side slopes of 2 (horizontal) to 1 (vertical), and locks 80 ft. wide and 641 ft. long between hollow quoins, or 600 ft. long in the clear.

Canal in Three Sections.

A study of the topography convinced me that a continuous canal from St. Louis to Cairo was impracticable on account of its probable cost, as it would involve many miles of canal trunk through bluffs from 75 to 200 ft. high. However, to show its impracticability more conclusively, an approximate estimate of such a canal was prepared, which is given further on.

It was decided, therefore, to lay out a canal across bottom lands only where the conditions were favorable, and elsewhere to use the natural bed of the river. The project as laid out consists of four stretches of open river navigation connected by three sections of canal, all of which are laid out on the Illinois side of the river. These have been designated the Upper Section, Middle Section and Lower Section.

A movable dam of the Chanoine wicket type has been located in the river near the upper end of each section, for the purpose of affording ample depth in the open river above the dam, and also for the purpose of securing an economical bottom grade for the adjacent section of canal.

The general location and length of each section of the canal and of each stretch of open river navigation is shown in the following table.

Lengths of Component Parts of Canal Project.

	Miles.
Open river from Eads Bridge to Meramec River	18.1
Canal from Meramec River to Kaskaskia River	39.8
Open river from Kaskaskia River to foot of Crains Island	16.1
Canal from foot of Crains Island to head of Devils Island	45.2
Open river from head of Devils Island to Commerce	18.9
Canal from Commerce to Pond Lily Crossing	15.5
Open river from outlet of canal to mouth of Ohio River	7.7
Total	161.3

The total distance by river from the Eads Bridge to the mouth of the Ohio River is 182.5 miles, so that the canal project will effect a saving in distance of 21.2 miles.

A guard lock is provided at the upper end of each section of canal. These are designated as No. 1, No. 4 and No. 6, on the accompanying maps and profiles. Locks Nos. 2 and 3 are located near the lower end of the Upper Section, with lifts of 15 ft. and 22 ft. respectively. Lock No. 5, with a lift of 32 ft., is located at the lower end of the Middle Section. Lock No. 7, with a lift of 38 ft., is located at the lower end of the Lower Section. The locks and dams are similar in design to those provided for the slackwater project.

The embankments have been designed with a top width of 16 ft., so that they may be used as highways by the people along the canal, to travel from the many private roads to the proposed highway bridges, which are located only at public roads. The side slopes are 1 on 2, the same as for the excavated portion of the canal. The cost of the earthwork has been estimated at 25 cents per cubic yard.

To prevent wave wash, the inside slopes are riprapped for a width of 9 ft., measured along the slope. This riprap will usually lie on the excavated slopes, but where the ground is low it will fall on the embankments. The cost of the riprap has been estimated at 60 cents per square yard.

A swing bridge with a draw pier to one side of the canal has been adopted as the most economical type for this project, the short span which swings over dry land being counterweighted. It was found that 54 highway bridges and 3 railroad bridges were required for the entire project. The average cost of a highway bridge has been estimated at \$55 000, and of a single track railway bridge at \$70 000.

Wherever it was practicable the culverts were taken under the canal, flushing devices being provided where needed. Where the topography was unfavorable to this arrangement, a culvert was provided under one embankment and the water taken into the canal.

Summary of Cost, Canal in Three Sections.

Upper Section	39.8 miles long	\$12 882 237
Middle Section	45.2 miles long	15 748 412
Lower Section	15.3 miles long	6 881 087
Total	100.3 miles long	\$35 511 736

Operation and Maintenance.

3 Locks and adjacent dams, at $15 000	$45 000
4 Locks, without dams, at $8 000	32 000
57 bridges, at $4 000	228 000
Dredging in river, 61 miles, at $1 000	61 000
Maintaining canal trunk, 100 miles at $200	20 000
Bank revetment	50 000
Total per annum	$436 000

Continuous Canal.

The project for a continuous canal involves cutting through the bluffs at Chester for a distance of nearly ten miles at a cost of two to five million dollars per mile. It also involves cutting through the bluffs at Thebes for a distance of about seven miles at a cost of one to two million dollars per mile.

A very expensive and unusual structure would be required at the Kaskaskia River, viz., an aqueduct with a drawspan. This would be necessary because the Kaskaskia is a navigable stream. The only alternative is a lock on each side of the river, so that boats may lock into the Kaskaskia River and out again, and a siphon under the Kaskaskia to carry the water supply for the canal. The estimates for the two plans do not differ materially.

The length of a continuous canal from Madison, Ill., to the mouth of the Ohio River is 158.9 miles. The estimated cost of such a canal is approximately $102 000 000.

The estimated cost of operation and maintenance is $596 000 per annum.

Alternate Project for a Continuous Canal.

An approximate estimate was also prepared for a canal which would cross over to the Missouri side of the river above the Kaskaskia River and then back again into Illinois at the foot of Liberty Island. This would avoid the high bluffs which follow the Illinois shore between these points, and also eliminate the aqueducts over the Kaskaskia River and Mary's River.

This project requires a lock on each side of the river at each place where the Mississippi is crossed, — or a net addition of two locks to the continuous canal project, on the Illinois side.

The estimated cost of such a canal is $76 542 000. The estimated cost of operation and maintenance is $606 000 per annum.

6. By Reservoirs.

(Abstracted from the Board's report.)

The theory of the improvement of a river by reservoirs is that the flood waters can be impounded in large quantities at the headwaters of the streams in such a way as to reduce flood heights in the lower reaches of the same streams; and that these waters, stored until the low-water season, can then be so discharged as to raise the low-water surface of the river and increase the navigable depths. This method of improvement was introduced many years ago on the Upper Mississippi River above St. Paul, and five reservoirs have been built with an area of 480 sq. miles, and a storage capacity of over 93 000 000 000 cu. ft. More reservoirs and more storage capacity were at first recommended, but so far Congress has not considered favorably the extension of the system. This system of artificial reservoirs is one of the largest in the world for regulating river discharge for navigation purposes, and yet the increase in height thereby obtained at St. Paul during the low-water period, about ninety days, averages only 14 in. The results so far noted range from 40 in., maximum increase in height in 1900, to 5 in., minimum increase in 1903. The river at St. Paul has a low-water width of only 400 ft. and an average low-water discharge during the navigation season of but 2 500 cu. ft. per second. The effect of the reservoir system diminishes as the river becomes wider, and finally disappears at the head of Lake Pepin, 51 miles below St. Paul.

In order to obtain the effects above named, it has been found necessary to commence the discharge of water from the reservoirs considerably in advance of the low-water stage at St. Paul, owing to the length of time that is necessary for the water to traverse the intervening river. After the discharge has been commenced at Lake Winnibigoshish, its effect is not especially felt at Lake Pokegama, the distributing reservoir, 63 miles further downstream, until after an interval of twenty-one days, and at St. Paul, 351 miles below Lake Pokegama, until after a further interval of ten days. In order to use this reservoir system for the benefit of the improvement of the river below St. Louis, it would be necessary to commence the discharge of the reservoirs at least two months before it was needed at St. Louis, and a still greater interval would be necessary for the improvement of the river below Cairo. Experience does not justify such long forecasts, and the service of the reservoirs would necessarily

have to be based on general annual averages, an unreliable and unsatisfactory basis. There have been occasions in the past when unexpected floods in the summer time would have been aggravated by any large additions from upper reservoirs. In order that reservoirs may give reliable service, they should be so located as to diminish the time of waterflow to a minimum. In the case under consideration this would necessitate the location of the reservoirs in the lower valleys of the tributaries, where the land is of great value, and such location would add enormously to the cost of the reservoir system, even if it were practicable.

While this method of improvement has been successful on the Upper Mississippi near St. Paul to the limited extent above described, a further extension of its application to a river of the dimensions of the Mississippi below St. Louis is attended with serious difficulties and must necessarily give results much less beneficial.

Theoretically a water supply is available above St. Louis sufficient to increase largely the low-water discharge of the Mississippi River at and below St. Louis. The maximum reservoir facilities of the river, including 10 000 cu. ft. per second that may come through the Chicago Drainage Canal and Illinois River, as recommended by the International Waterways Commission, amount to about 69 500 cu. ft. per second for ninety days, equal to about 540 000 000 000 cu. ft. total storage.

The maximum of 540 000 000 000 cu. ft. total storage which might be obtained by reservoirs in the Mississippi River basin from the Illinois River upward could not maintain throughout the year more than 8 ft. available depth between St. Louis and Cairo, the increased discharge from the reservoirs tending to create a wider channel rather than a deeper one, and being useful, therefore, only as an auxiliary to other methods of improvement. To hold the stage at a controlling depth of 14 ft., between St. Louis and Cairo, would require a storage capacity of over 5 000-billion cu. ft., or about ten times what has yet been found possible.

7. Combination of Methods.

(Abstracted from the Board's report.)

The Board is of the opinion that the most practicable method of obtaining and maintaining a navigable channel of 14 ft. depth from St. Louis to Cairo is by the completion of the project of 1881 for partial regulation in such a way as to secure a permanent controlling depth of 8 ft., and then to rely upon dredging for

securing and maintaining any further increase of depth; the contraction works to be so located as to be in harmony with further works of improvement by complete regulation if in future such works be found necessary and advisable.

The estimated cost of completing the 8-ft. project is $21 000-000 and the cost of dredging plant for obtaining the additional 6 ft. is estimated at $3 600 000, making a total of $24 600 000. The cost of maintaining the improved channel is estimated at $1 500 000 per year.

Comparison of Estimates.

(Projects for 14-ft. Waterway from St. Louis to Cairo.)

Plan.	First Cost.	Operation and Maintenance.	Operation and Maintenance Plus Interest on Cost at 3 per Cent.
1. By dredging alone	$6 000 000	$2 000 000	$2 180 000
2. Complete regulation	53 000 000	500 000	2 090 000
3. Slackwater project, by movable dams and locks	25 000 000	382 000	1 132 000
4. Slackwater project, by fixed dam and locks	57 000 000	253 000	1 963 000
5. Lateral canals, Canal in three sections	35 500 000	436 000	1 501 000
5. Lateral canals, Canal in two sections	76 500 000	606 000	2 901 000
5. Lateral canals, Continuous canal	102 000 000	596 000	3 656 000
6. By reservoirs	Impossible		
7. Combination of methods	24 600 000	1 500 000	2 238 000

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1911, for publication in a subsequent number of the Journal.]

THE HYDRO-ELECTRIC POWER PLANT ON THE JHELUM RIVER IN KASHMIR, INDIA.

By Heinrich Homberger, Member of the Technical Society of the Pacific Coast.

The advent of the long-distance transmission of electric power — the first practical example was the transmission from Lauffen on the Neckar River to Frankfort on the Main on the occasion of the electrical exposition held there in 1891 — has resulted in a remarkable development of hydraulic power engineering. The new field brought more exacting requirements, especially in the matter of power-generating units, their capacity, reliability of operation, efficiency and regulation, all of which have to-day reached a degree of perfection which leaves hardly anything more to be expected or desired.

In a hydro-electric power plant practically all branches of engineering find their share of work. The civil engineer furnishes not only the surveys for storage reservoirs, canals, tunnels, pipe lines, power house and power transmission line, but also has great opportunities to display talent and ingenuity in the selection and actual construction of all these items. The mechanical engineer had to develop the machinery, and step by step only did this reach its present degree of perfection; with every new plant there remains for him the all-important task of selecting the proper type, size, speed and arrangement of units for the proposed power system, also the design of piping and connections between the forebay and the machines, and of the mechanical equipment of intake, forebay, pipe lines and power plant, details which have quite often been sinfully neglected even in the most recent plants in this country, partly on account of a dearth of sufficiently well-trained and experienced specialists in this line, and partly on account of a lack of appreciation of the value of the advice of such specialists from the side of the promoters and managers of power enterprises, who still adhere to the old methods of the pioneer who could not possibly do things differently, because he had new problems and unforeseen conditions to contend with and was thrown entirely on his own resources of pluck, perseverance and ingenuity.

Finally, the electrical engineer has a most important and inviting field, although to-day his part of the work is more standardized than any other element of the combination, and few important or radical changes have been made in recent years.

Wherever water powers of any magnitude are available, combined with a market for the power that can be developed, national and private enterprise have soon recognized the possibilities, and great energy and not a small amount of courage were displayed for the last two decades to develop these gifts of nature for the benefit of mankind. Just as the building of railways in sparsely settled countries has the result of creating facilities which attract population and capital, so the opportunities of cheap power and light open up territories which had been overlooked by the settler and investor; it is not always the case that the demand brings the development of facilities; on the contrary, frequently the offered facilities increase the demand, and one-time luxuries soon become necessities to the people.

The progress of civilization cannot be stopped; lack of understanding may retard it, shortsighted or selfish policies may hinder it, the desire of governments to increase their revenues may reduce the earning capacity of water-power developments, but the time will come when all streams will be harnessed and when man will consider it a crime to use up the limited and exhaustible supply of fuel for the generation of power, light and heat anywhere but on shipboard. " Conservation " is a misnomer as far as water power is concerned; it is practically the only inexhaustible source of power we know of to-day.

Great Britain, with its all-enveloping conservatism, has done less in the development of water power than any civilized country, and the colonies have outdone the mother land. The Indian Empire affords marvelous opportunities both for cheap generation of power and for consumption in large quantities. The first hydroelectric plant of magnitude was started in Mysore in Southern India in 1900, utilizing the power of the Cauvery River, principally for the benefit of the famous Kolar Gold Fields, ninety miles distant, and in 1904 11 000 h.p. had been developed. The success of this enterprise, which was engineered by officers of the British Army, created a desire to look for other fields to be conquered, and the vassal state of Kashmir offered an attractive opportunity.

The beautiful valley of Kashmir, of which Srinagar is the capital, with its colony of houseboats, lies 6 000 ft. above the level of the sea, the mountain Haramukh (16 903 ft.) guarding

the valley of the Sind, while at a farther distance rises the sacred mountain Mahadeo.

Kashmir was once a lake, and it sometimes suffers now from terrible floods, receiving as it does the rainfall of 3 900 square miles and having but one outlet, the gorge of Baramulla to the river Jhelum, — the Hydaspes of Alexander the Great. Wular Lake, which is twelve and a half miles by five miles in extent, is said to flow over the remains of a city famed for its wickedness, which was destroyed by earthquake and flood. The boatmen plying on the lake say that the ruins have been seen in the water.

Maharaja Sir Pertab Singh holds sway over a territory of 88 000 square miles, some of which is amongst the most fertile in the world, peopled by about three millions. Himself ranking as one of the foremost Hindu princes in India, more than half the population over which he rules is Mohammedan.

In 1905 the maharaja was granted fuller independent power of administration by the supreme government of India, and Kashmir bears witness to the wisdom and sense of proportion exercised in its use.

The ruler of Kashmir has applied his knowledge of science, as well as of medicine and law, to the government of the country, and Kashmir is now opened out by a railway system which is to be entirely worked by electricity. The latest and no doubt the largest public-works undertaking just completed in Kashmir is the Jhelum electric power installation.

History of the Project.

The report and recommendations of Major de Lotbiniere, R.E., C.I.E., — by whom the preliminary investigations and reconnaissance survey of the works were completed in 1904, — having been finally accepted by the durbar of Kashmir, it was decided to commence construction in the spring of the following year. The report had located the site of the head works nearly opposite the ancient temple at Baniar, eighty-five miles on the Jhelum Valley highway, with forebay and power house at Mohora, about six and one-half miles farther down, the available working head being approximately 400 ft. The Jhelum Power Division was formed without delay, with headquarters at Baniar, where the old state sawmill buildings and road bungalow were placed at the disposal of the electrical department by the state engineer, which afforded, after some alterations and renovations, suitable accommodation for the resident engineer, divisional office, store and office establishment. These buildings were

subsequently transferred formally, at a valuation arrived at by mutual agreement. By the latter end of May, most of the land required had been taken up and demarcated, and contracts allotted on open tender for the construction of head works, and upper sections of the supply channel, ground being first broken on the 26th of that month, near the head works. Meanwhile, check levels had been taken from the proposed site of the head works to those of the forebay and power house, and the accuracy of the preliminary work in this connection was fully established. Careful and detailed inspection of the supply channel alignment along the hillsides showed that a wooden flume presented the only practicable method of conveying the water required over the greater part of the six-and-one-half-mile route. The state forest department having undertaken the supply of the whole of the timber (deodar) required, then estimated at 300 000 cu. ft., and details having been settled, indents and full information in this connection were promptly submitted to the conservator of forests. Major de Lotbiniere, C.I.E., left Kashmir for Europe and America on deputation at the beginning of July, 1905, to arrange preliminaries, contracts for the hydraulic and electric plant, and also for plant and machinery required in connection with the proposed dredging operations. Major H. A. D. Fraser, R.E., was appointed as engineer and agent in London to the Kashmir durbar in connection with the Jhelum power installation in June, 1906. Mr. A. C. Jewett was appointed in this capacity from December, 1906, and was located at the Schenectady works of the General Electric Company, New York, whose tender for electrical plant had been meanwhile accepted.

The Development of Water Power.

The present works, in so far as they relate to the development of water power, have been constructed to develop 20 000 h.p. at Mohora, of which but 5 300 will be utilized at present, the generating plant comprising 4 units only, each of 1 000 kw. The site for the head works was fixed finally at a point some 500 ft. above that originally selected, gaining thereby an additional head of about 10 ft., and reducing the excavation on the channel line considerably. The general design is very much like that usually adopted for the head work of an ordinary irrigation canal. It consists of a draft or intake channel, regulating basin and scour sluice, the latter having four outlets, each 4 ft. by 7 ft., with the sill level 2 ft. below that of the lower main sluices.

Of main sluices there are ten, in two tiers, one above the

other, for use at high and low river level. These discharge into a small regulating basin, at the contracted end of which a gate 8 ft. wide and 9 ft. high gives admittance to the supply channel. These gates are all of steel, and provided with suitable screw gearing for manipulation. All outlets are protected by heavy iron gratings. A vertical grid-barrier of old rails, erected vertically across the intake channel, together with massive floating timber booms securely anchored, afford further protection from damage by passing timber, vast quantities of which are floated down the river each flood season by the state forest department. The capacity of the main sluices is over 600 cu. ft. per second, with minimum head at low water. During construction a temporary bund was thrown around the site to exclude the river, and constant pumping operations were necessitated during the whole of the working season of 1906, at the end of which the works had been brought well above high flood level. The masonry throughout is of gneiss bowlder stone, obtained near the site, in soorkhee mortar, Portland cement being used in both concrete and masonry of foundations.

Masonry Conduit.

The supply channel takes the form of a masonry lined and floored conduit, and wooden flume; the latter construction was resorted to only when the former was found impracticable.

The total length of channel is 6.5 miles, made up of

	Miles.
Masonry lined conduit	1.57
Silt basin	0.11
Wooden flume	4.67
Rock tunnel, unlined	0.15
Total length	6.50

A masonry lining was inevitable, owing to the nature of the soil, loose shingle, bowlders, and silt, in irregular formation. The thickness of masonry lining averages 2 ft., with backfilling of clay concrete; that of the floor being 6 in., all sub-laid with soorkhee concrete of 6 in. minimum thickness. The whole is of coursed stone rubble in soorkhee mortar, and the water-bearing surfaces are pointed throughout with Portland cement. The dimensions of the masonry duct are 11 ft. wide and 9 ft. minimum height, the section is rectangular, with a uniform grade of 1.05 per 1 000, this being constant from head works to forebay. The aggregate length of the masonry conduit is 8 300 ft., of which

Fig. 12. Street in Mohora. Sections of Pressure Pipe. Butcher Shop of Construction Camp in Foreground.

Fig. 1. Intake near Baniar, Regulating Basin, Main Sluices, Grid Barrier and Floating Timber Booms.

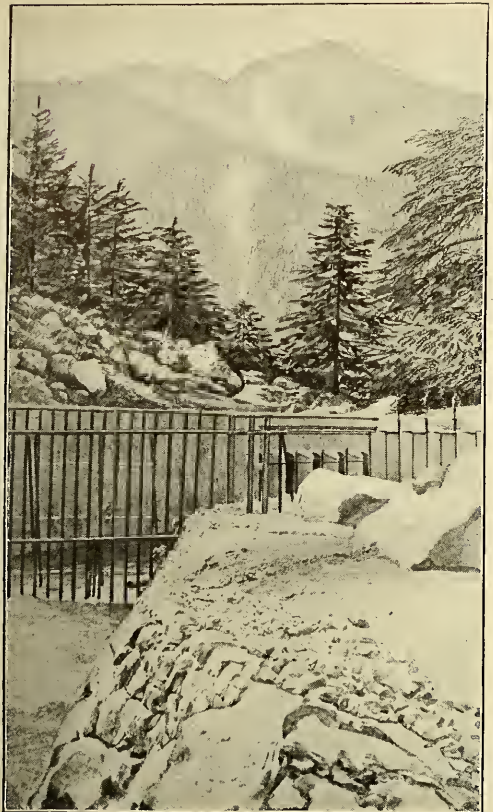


FIG. 2. INTAKE. DETAIL OF GRID BARRIER.

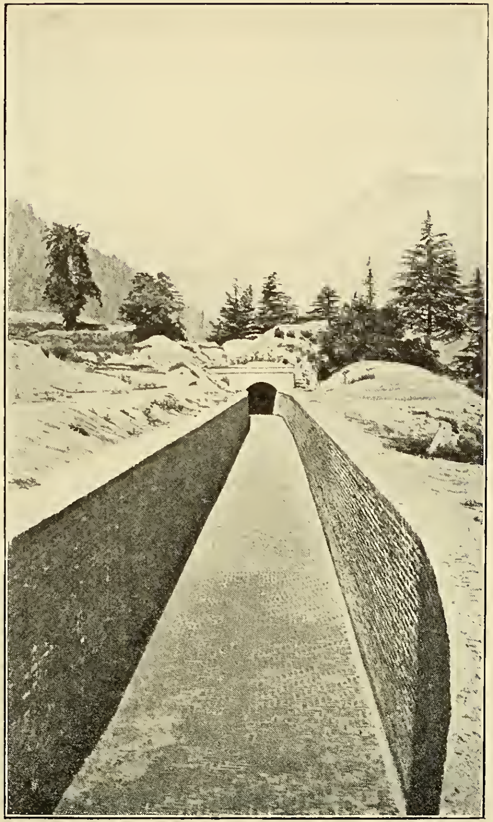


FIG. 3. MASONRY-LINED CONDUIT; IN BACKGROUND THE ARCHED-OVER TYPE OF CONDUIT IN "CUT AND COVER."

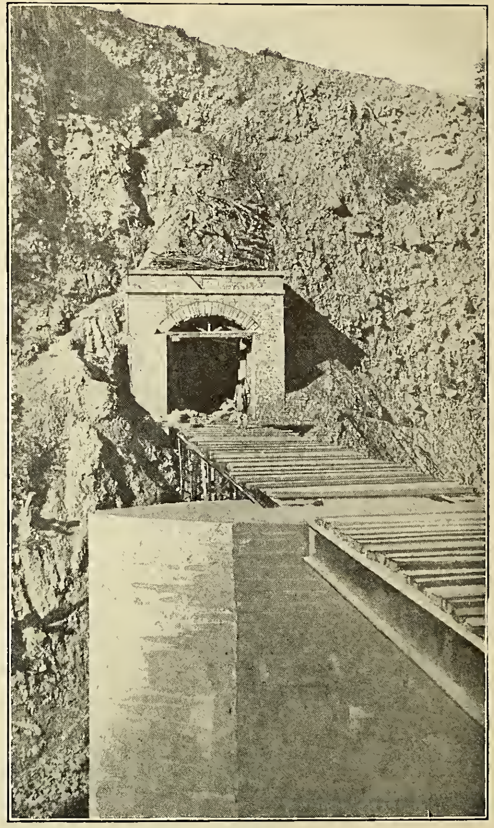


FIG. 4. TUNNEL NO. 3 NEAR CHENANWARI, AND AQUEDUCT CROSSING GORGE.

3 200 ft. are arched over in "cut and cover." The locations of this type of channel are as follows:

From the head works to the Baniar stream, length of 3 400 ft., of which 1 000 ft. (chains 7 to 17) lie in very deep cutting, the arched roof being superlaid with earth cover to a depth of from 10 ft. to 20 ft. From the left bank of the Baniar stream to the head of the silt basin there are 450 ft. of cut and cover, with 400 ft. of similar construction below the basin, and 153 ft. of ordinary channel. At Rampur, the masonry conduit recommences at chain 73, in continuation of an interpolated section of wooden flume, passes beneath the Jhelum Valley Road, and across the camping ground of His Highness the Maharaja Sahib to chain 91, being at either end about 1 000 ft. long; just below Rampur, chains 102 to 107, the channel forms a subway on a reverse curve, below the bed of a large and at times dangerous nullah. A similar subway passes beneath the bed of a nullah at Chenanwari (chain 257), followed by 150 ft. of arched conduit in cut and cover, and about 200 ft. of open masonry channel immediately beyond tunnel No. 3, at Chenanwari. From the lower end of tunnel No. 6, the masonry conduit runs across the flats of Mohora plateau, for a length of about 13 000 ft., where it debouches into the forebay; this last section is lined and floored in brickwork.

The Wooden Flume.

It was, as already stated, decided at the outset that a wooden flume presented the only practicable method of conveying the water along the steep hillsides, which are of loose formation generally with side slopes ranging from 1 in 2 to 1 in 1, and averaging 1 in $1\frac{1}{3}$. A woodworking plant was imported and installed with two portable engines in a temporary mill at Rampur where the whole of the tongued and grooved planking, etc., for floor and side lining (over one million linear feet) and other miscellaneous work, were dealt with. The rectangular flume frames were all worked up by hand at site. Final alignment having been demarcated, it was decided that the track on which the flume was to be built should take somewhat the form of an ordinary hill roadway with a uniform grade of 1.05 in 1 000. A continuous retaining wall of coursed rubble laid dry, battered 1 in 4 to 1 in 3, supports the hillsides, and a drop wall of similar construction protects the outer edge of the track from erosion, etc. The minimum width of the track is 12 ft. and it is metaled throughout. The dimensions of the rectangular wooden flume are, 8 ft. 4 in.

wide and 8 ft. 6 in. between floor and under sides of caps; these are canted at the outer ends in rounding sharp curves to counteract centrifugal wave effect. The minimum radius of curvature on the line is 50 ft., and these curves occur at three points only, viz., Baniar aqueduct, entry to tunnel No. 2, and at No. 6 aqueduct over the Mohora nullah.

The present general watertightness of the flume leaves little to be desired; recent observations, most carefully taken, have shown that the total leakage in four miles of practically consecutive channel of this description is but little more than half a cubic foot per second. The flume has been necessarily roofed throughout to exclude soil, etc., from the hillsides above; this includes also the space between the flume and retaining wall at roof level.

The capacity of the flume is well over 500 cu. ft. per second at full depth of flow (8 ft.) and with a velocity slightly in excess of 8 ft. per second. This is equivalent to over 18 000 h.p. at the power house, Mohora.

Deodar (Cedrua Deodara), from Kashmir forests, has alone been used in construction of the flume throughout, and this cedar is reputed to be about the best of its class in the world. About 700 000 cu. ft. of this material have been used on the work.

The total length of wooden flume is 24 666 ft. (4.67 miles); its building was commenced early in 1907, and by the end of the working season, i. e., December, 1907, 18 600 ft. had been finished. The work was resumed at the end of March, 1908, and carried to completion on the 1st of August, 1908.

The silt basin, a most essential adjunct, has been constructed just beyond the left bank of the Baniar stream at a point 4 100 ft. from the head works, below which this was the first suitable site available. It is proposed to install a floating sand pumping plant in the near future, with portable engine, to clear the silt from the receptacle at the bottom of the basin, as may be required from time to time.

The Aqueducts.

Of aqueducts there are five major and five minor, over gorges and small watercourses traversed by the supply channel. Of the major aqueducts, the first is a 76 ft. skew span over the Baniar stream, two thirds of a mile below the head works. Here the girders, which are of "Warren" type, are inverted, the wooden flume being snugly ensconced between the booms, on the lower of which it is thus carried. This affords maximum headway, which

FIG. 5. FLUME IN COURSE OF CONSTRUCTION.
DRY-LAID RETAINING WALL.

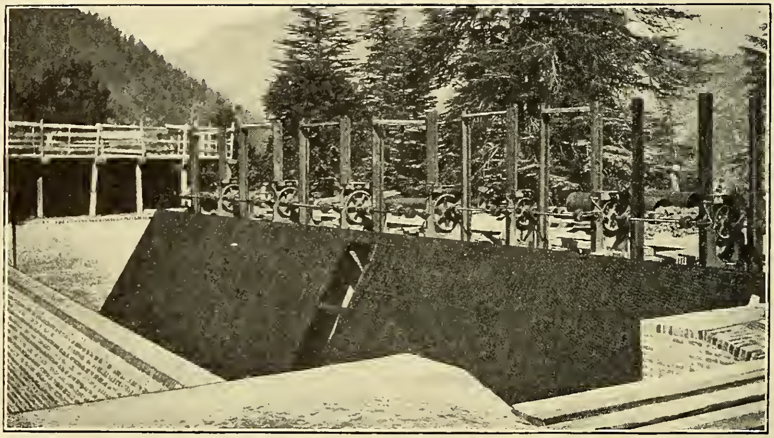


FIG. 6. FOREBAY, GRATING AND OPERATING MECHANISM FOR MAIN HEADGATES.

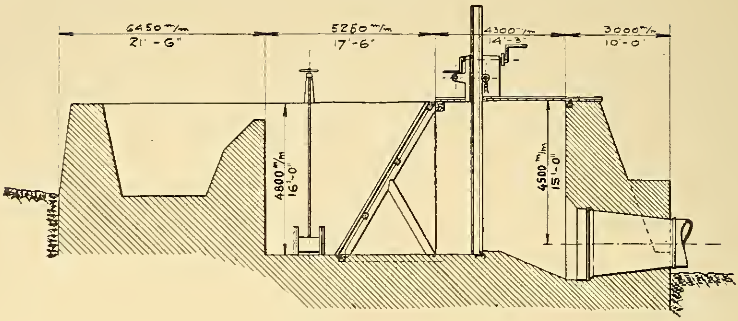
was rather limited, for the passage of timber and driftwood, etc., large quantities of which are swept down this stream at times, during prolonged freshet periods. The waterway immediately above this aqueduct, which was rather confined between rock banks, has been considerably improved by the clearance of an obstructive roof of hard rock. The other four major aqueducts are of similar design, but the girders drop from their bearings, and the flume is carried on the upper boom. The clear spans are in each case 80 ft. and the depth between the boom centers 10 ft.; the headway from the bed of the gorge below is from 35 ft. to nearly 60 ft. in the case of the last one at Mohora. These aqueducts cross the Chenanwari and Mohora gorges, together with two large intervening nullahs. There are six tunnels on the line, of aggregate length approximately 2 000 ft.

Three snowsheds have been constructed over the wooden flume at points where snowdrifts are known to be exceptionally heavy at times. These, it is hoped, will be found effectual in preventing damage to the flume by snow avalanches. These sheds are situated at chains 117, 123 and 205, between Rampur and Chenanwari, and were constructed from rejected planking and timber poles. It was found during the progress of work that during periods of abnormal rainfall very heavy trees and driftwood, etc., as well as bowlders, are likely to be swept down two ravines, situated about half a mile below Rampur, the flow of water in which is ordinarily quite insignificant. The means adopted to forestall anticipated trouble in this respect took the form of very heavy timber floors or aprons, laid over the flume, of which they are quite independent, and supported by substantial crib-work abutments of logs and stones. The timbers forming these aprons are securely dog spiked and bolted, the floors are flanked, with side walls formed of heavy poles bolted to verticals, in stockade fashion. These over-chutes afford ample clearance way for the largest logs or trees that can possibly be brought down, and they have been in existence, together with the snowsheds, for over two years, with most satisfactory results.

The Power Plant in General.

For the design of the power plant proper, consequently also for the arrangement of forebay and pipe lines, three different points of view were of decisive influence.

(1) The fact that the plant was to be located at a point far distant from the origin of the machinery and mateiials installed,



SECTION C–D.

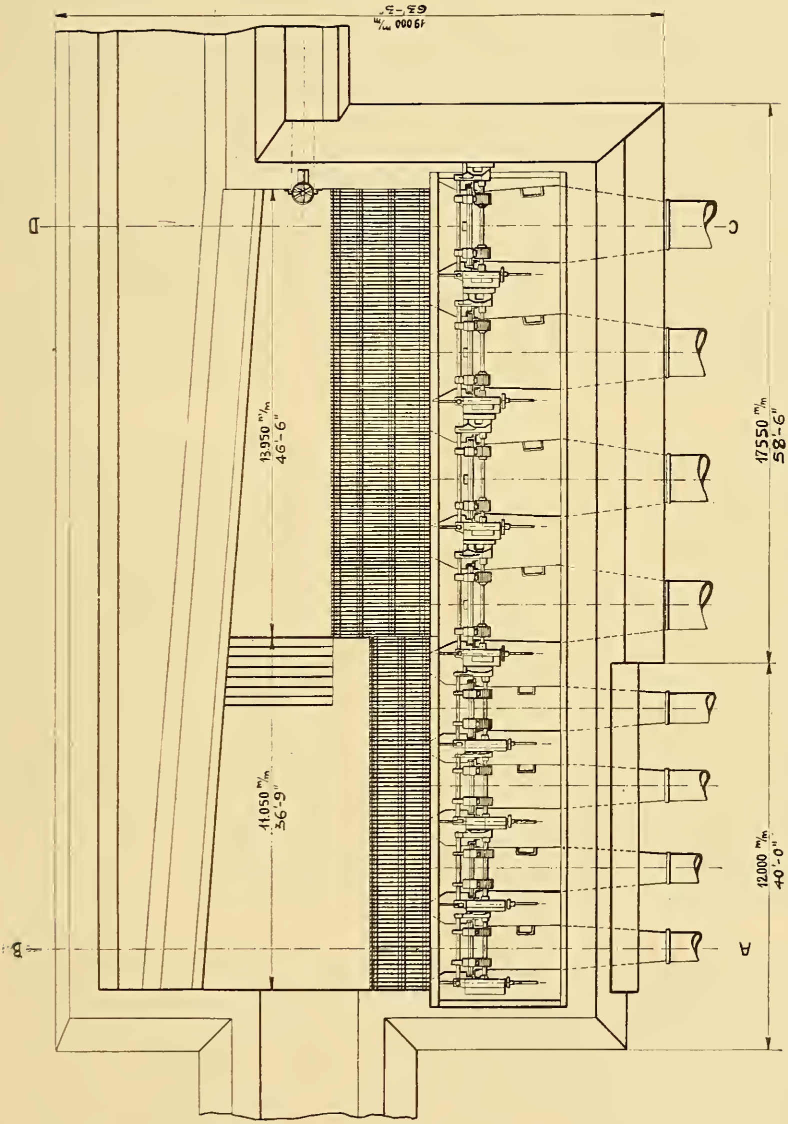
and the impossibility of procuring repair parts without considerable loss of time.

(2) The unfavorable conditions of transportation, as the power plant is accessible only over a mountain road 200 miles long from the railway terminal Rawalpindi, crossing altitudes as high as 7 000 ft. above sea level. All material has to be moved by beasts of burden (bullocks); the greatest permissible weight was 4 tons, preferably 2 tons, as the rates for transportation are based on a sliding scale, which goes up rapidly from the 2-ton point. The maximum weights had to be hauled in carts drawn by four animals, two hitched to the front and two to the back of the vehicle.

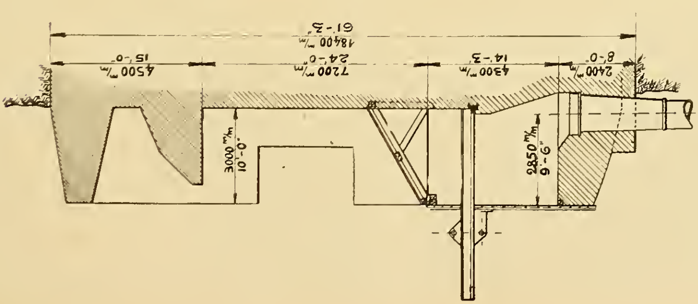
(3) The power plant was to be installed and operated principally by natives without any experience in this sort of work, and on whose ingenuity, in extraordinary cases, one can count only within very moderate limits.

It was decided, therefore, not to go beyond a unit size of 1 000 kw. for the first installation of 4 000 kw., to make each of the units entirely independent, including a separate pressure pipe, main gate valve near the machine and sluice gate at the forebay. For the proposed extension of the plant, however, pipe lines of larger capacity have been planned, each of which would be sufficient to feed two 1 000 kw. units. If the Jhelum Valley Railway should be completed in time for the next following installation of generating apparatus, a larger size of units may also be considered.

The exciter units take their water from a double header pipe, running along the uphill wall of the power house building. This is connected with the main pipe lines by means of special gate valves. The small motor generator set, to be mentioned later, and the fire service also, connect with this double header.



FOREBAY. JHELUM RIVER POWER INSTALLATION.



SECTION A-B.

The Forebay.

The forebay is located on the Mohora plateau immediately overlooking the power station. It has been built, together with the last 1 000 ft. of conduit, of brickwork in soorkhee mortar, cement pointed, as stone was not readily available near the site. The extension of the spillway to an existing nullah on the left flank consists of about 500 ft. of wooden flume, and at the foot of the nullah a capacious masonry culvert beneath the Jhelum Road, followed by 300 ft. of similar wooden flume, conveys the surplus water to the spill channel from the power house tailraces, and so back to the river. The forebay has been constructed for the full capacity of 20 000 h.p., and all fittings, gratings, gates with gearing, and inlets for future pipe lines, have been erected complete and in position. The large tapered steel inlets for future extensions have been closed with brickwork which can readily be removed when required. The gates, of which there are eight in all, — four of the smaller size for present, and four larger ones for future use, — are of deodar wood, made at site; the metal fittings, gearings, etc., for manipulation were imported.

Each gate controls and isolates a separate chamber containing the bell-mouth inlets, which perforate the outer main front wall, giving admittance to the penstock pipes. The bed of the nullah, on left flank of the forebay, being liable to heavy scour, it has been recently decided to spill from the aqueduct over the Mohora nullah, some 1 500 ft. higher up the channel, where the bed of this nullah is of very hard rock.

The Pressure Pipes.

Each of the pressure pipes is 750 ft. long, with no horizontal curves, and two bends in the vertical plane are made in the form of welded angle sections. One of the joints near the entrance taper is a slip joint, packed with hemp, in order to permit possible longitudinal movement of the pipe line.

The pipes are made of welded steel, each section is 10 ft. long between the rows of rivets which form the circular joints. The diameters are reduced three times, beginning with 36 in. at the top, and ending with 30 in. at the lower end, the thickness of the plate increasing from 5 mm. to 8 mm. Each course has two longitudinal welding seams, made by the water gas process, and is tapered to the double thickness of the plate, so that every course fits the next following one. The ends of each course were carefully finished and fitted at the works and provided with calk-

PRESSURE PIPES IN COURSE OF CONSTRUCTION.

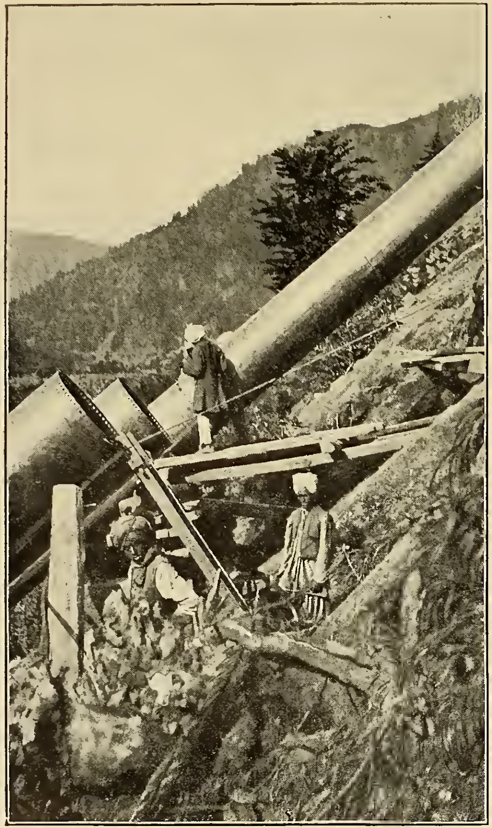


FIG. 7.

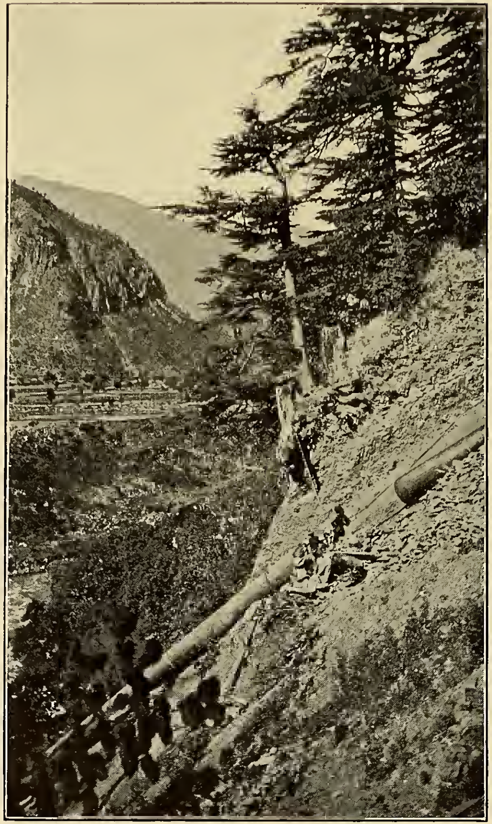


FIG. 8.

FIG. 9. FROM ROOF OF POWER HOUSE.

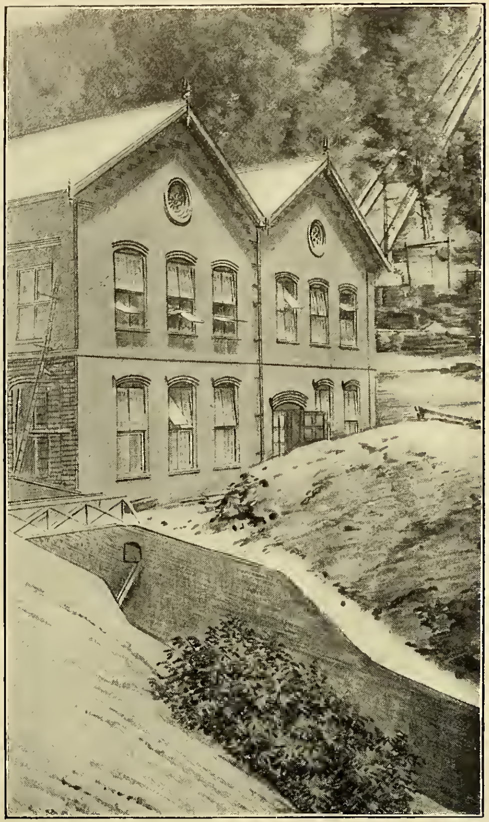


Fig. 10. Power House Building (end view)
Tailrace.

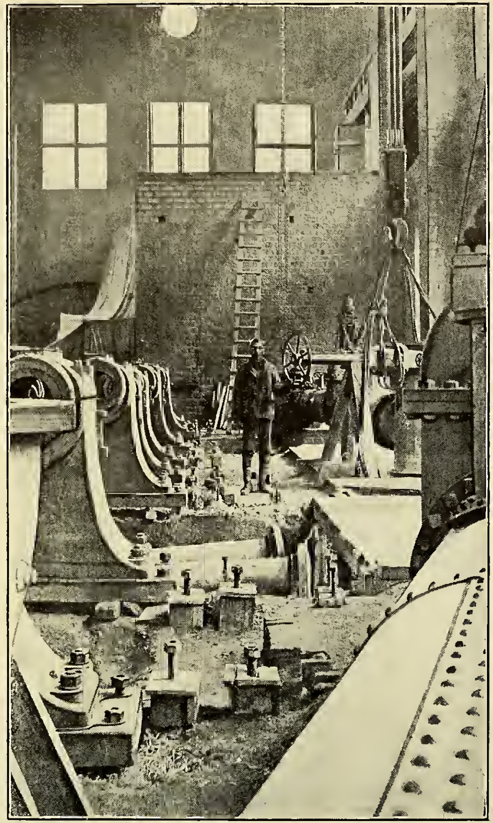
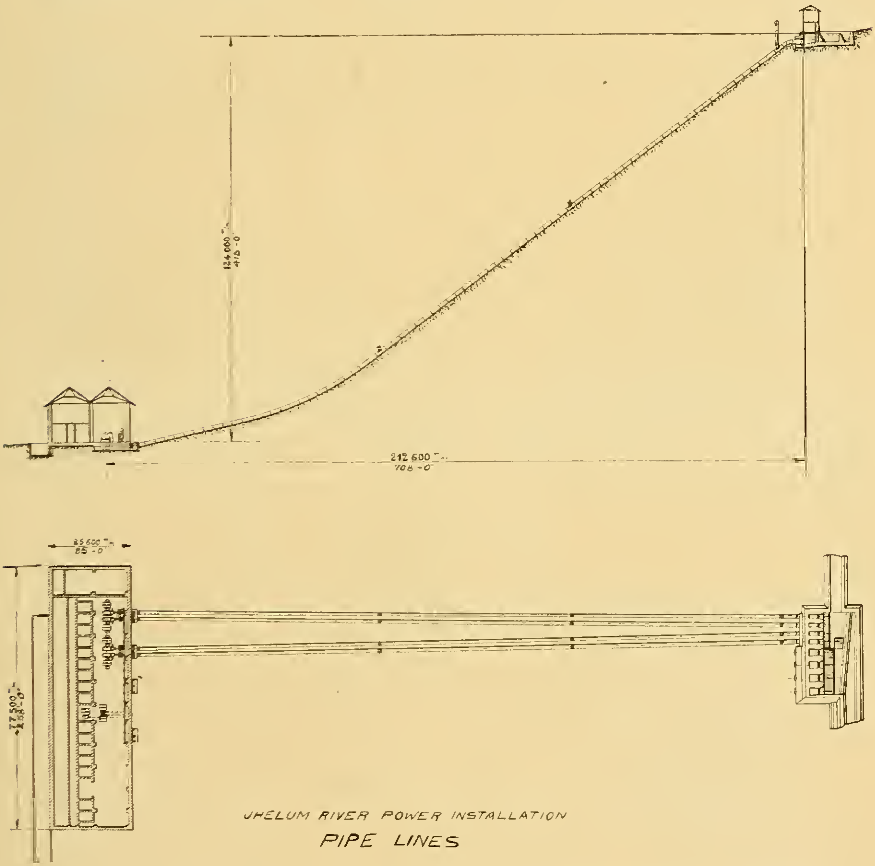


Fig. 11. Power House Interior.
Bearings for Main Generating Units.
Exciter Header Pipe in Background.

ing edges; all rivet holes were drilled from templates, and every course was tested hydraulically to one and one-half times the static head. The welded seams were tested for tightness by tapping with a short-handled sledge hammer while the pipe was under test pressure. All pipes were coated inside and outside with a rust-preventing compound, and carefully marked before shipment, so that a mistake in assembling was practically impossible.



JHELUM RIVER POWER INSTALLATION

PIPE LINES

For shipment, four sections of different diameters were telescoped into each other and held in place by wooden wedges driven into the spaces between the pipes at each end of the bundle. Finally the ends of the bundles were closed by heavy wooden covers, drawn together by means of three threaded half-inch iron rods with nuts. These were placed close to the inside of the innermost or smallest diameter pipe. Owing to this careful way

of packing, which also resulted in a great reduction of space and saving in freight, these light pipes stood the long trip with transshipment at four places, Hamburg, Bombay, Karachi and Rawalpindi, very well, and arrived at the plant in perfect condition.

The laying of the pipe lines began from the bottom; the bottom section of each pipe is provided with a welded flange by means of which it was bolted to a heavy cast-iron fitting of slight curvature. This fitting has a soleplate cast to it and acts as a thrust block, being bolted to a heavy foundation pier. The entire pipe thrust is taken up at that point. To prevent a dangerous vacuum in case of the sudden emptying of a line, automatic air inlets are provided at two points; also a standpipe immediately below the forebay.

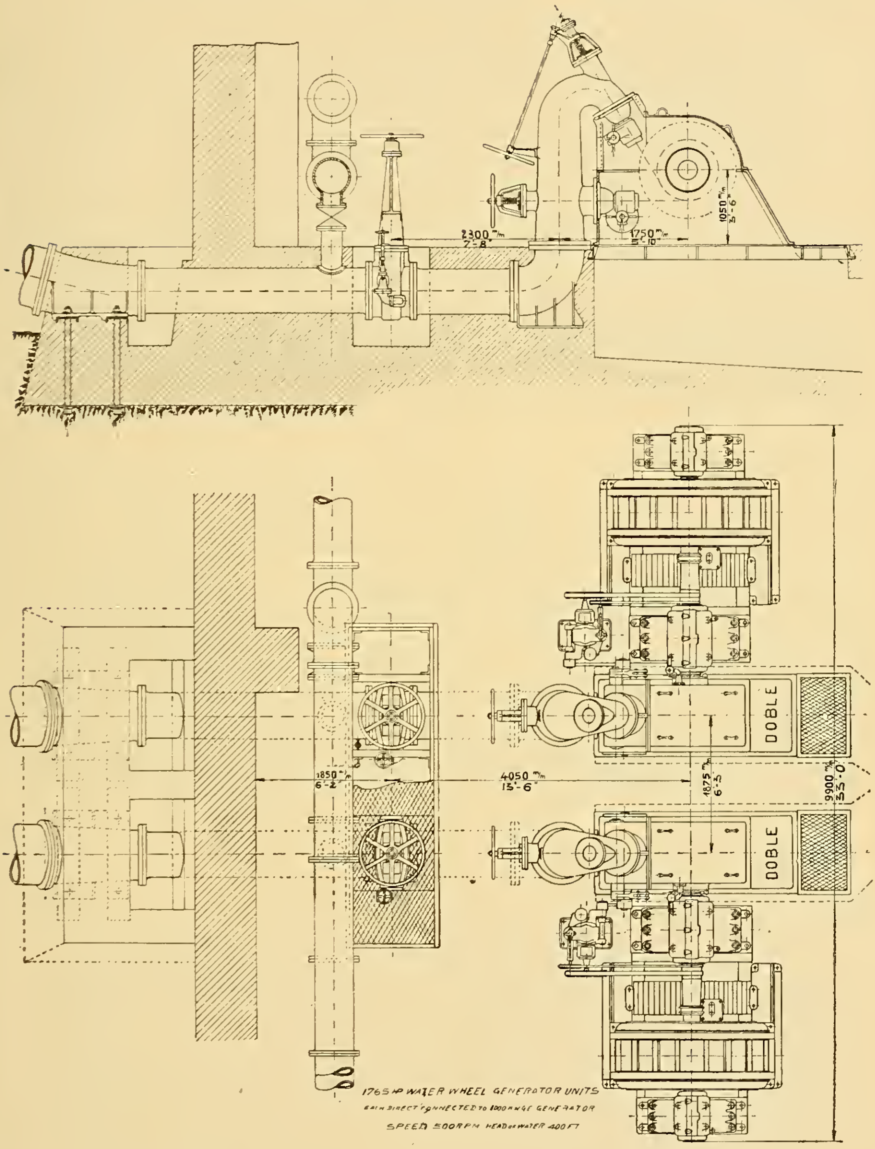
The material for the pipe lines arrived in 1907, well towards the end of the season suitable for pipe laying; nevertheless, work was started immediately, and when it had to be stopped in December, all four lines had been finished as far as the Jhelum Valley Road, under which they pass through tunnels, about 156 ft. from the power house. Early in April, 1908, work was resumed, and the installation was finished by the first of August, simultaneously with the completion of the flume.

Where the pipes are exposed they are carried on brick piers, which are 20 ft. apart.

The Power House.

The very heavy excavation in difficult hard bowlder soil, that had necessarily to precede the commencement of the power house, was begun towards the end of 1905 and was completed in June, 1906. The design for the building was adopted after determining present limits as regards length, etc., and adapting details to local requirements. The steel trusses for the roof were procured from Bombay. The building was laid out early in July, 1906, and brought to its main floor level by the end of the working season. It was eventually completed — that is, in the matter of walls, roof, and doors and windows — by end of November, 1907.

The foundations and superstructures to the gallery level, i. e., 20 ft. above the main floor, are of coursed rubble masonry, and the walls above this of mortar class brickwork, all in soorkhee mortar. All concrete and masonry work in the tailraces and wheel pits, etc., is in Portland cement soorkhee mortar. Concrete was used in all ordinary foundations, etc.

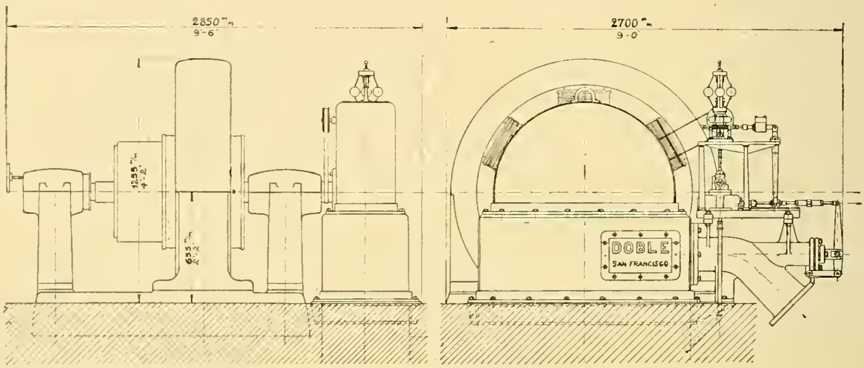


The main floor consists of 6-in. soorkhee concrete, with Portland cement surface rendering; the gallery floors are of Portland cement concrete 7 in. thick, with expanded metal reinforcement; the whole is carried on steel beams, of suitable sections and spacing.

The roof consists of galvanized iron corrugated sheeting,

22 B.W.G., laid upon 1-in. kairoo planking, over common rafters and purlins of similar wood, the whole supported by steel trusses of French type, spaced at 12 ft. 4 in. centers. The roof is double, in two spans, one of 39 ft. 2 in. and one of 40 ft. 2 in., with central valley gutter and down pipes at gable ends.

The internal dimensions of the building are 183 ft. 6 in. long and 76 ft. wide at main floor level. Two additional tail-races and foundation pits for four more machines of similar size to those now installed, together with six extra transformer compartments, have been provided within the existing building. Should any deviation from the existing type of machines be made in future installations, these foundation pits, etc., can be readily



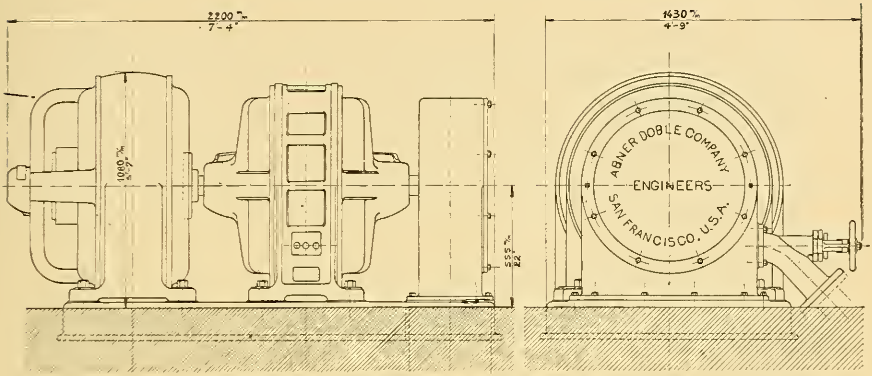
JHELUM RIVER POWER INSTALLATION

285 HP EXCITER WATER WHEEL UNIT

SPEED 500 RPM HEAD OF WATER 400 FT.

adapted. A spacious machine shop has been provided at the east end of the power house, with an adequate outfit of machine tools and motor-driven shafting, etc. This portion of the building also contains a complete oil-treating plant and a specially constructed pit, to facilitate work upon the main transformers. This generating plant began to arrive late in 1906, by the end of which little more than some line material had been received. Further arrivals accumulated in Rawalpindi during the winter, when the roads to Kashmir are usually closed to heavy traffic by reason of snow. In the spring, however, carting was resumed, and so well maintained that practically the whole of the plant had been delivered by the end of 1907.

A substation at Srinagar has been erected on a suitable central site, within the state silk factory enclosure.



JHELUM RIVER POWER INSTALLATION

50 HP MOTOR GENERATOR WATER WHEEL SET

SPEED 750 RPM HEAD OF WATER 400 FT

Hydro-Electric Machinery.

The machinery so far installed in the power house consists of the following items:

4 main generators, 1 000 kw., 2 300 volts, 60 cycles, 500 rev. per min.

4 main water wheels, 1 765 h.p., 500 rev. per min.

6 transformers, single-phase, delta-connected for 30 000, 50 000 and 60 000 volts.

2 exciter generators, 150 kw., 125 volts, 500 rev. per min.

2 exciter water wheels, 275 h.p., 500 rev. per min.

1 motor-generator water-wheel set, 50 h.p., 125 volts, 720 rev. per min.

Water-Wheel Units.

As mentioned before, the main generators are of 1 000 kw. rated capacity, and the water wheels, mounted upon the same shaft as the rotor fields, develop a maximum of 1 765 h.p. In order to reduce size, weight and cost of the units, a turning speed of 500 rev. per min. had been selected, although slower speed machines would have given a higher efficiency. This high speed required the application of two jets, plying on one single water-wheel runner.

The main shaft is carried in two bearings of 11-in. and 8-in. diameter respectively, the generator is located between the bearings and the water-wheel runner is mounted on one extended end of the shaft. The generator rotor was pressed upon this shaft after arrival at the plant; the water-wheel runner, cast in one piece, is bolted to a flange, forged upon the end of the shaft, by fitted bolts.

Water is conveyed to the machine from below; the main supply pipe is located below the floor; it has a diameter of 24 in. and is equipped with a main gate valve of the same opening; it is carried up through a 90-degree elbow and terminates in a casting forming a double nozzle in such a way that one jet strikes the wheel horizontally below the shaft and the other one from above it at an angle of 60 degrees from the horizontal. Both nozzles are equipped with regulating needles for hand operation.

The instantaneous regulation is accomplished by cylindrical jet deflectors, and these are operated simultaneously by a vertical Lombard oil governor. This form of regulation in itself does not afford any economy in water consumption, but it was resorted to principally by reason of its simplicity, and, furthermore, cheap labor permits of an ample operating crew in the plant, so that hand operation of the needles and starting and stopping of entire units can be carried to an extreme, which in a plant in this country would rather overtax the operators.

The water-wheel housings are entirely of cast iron, and, for the purpose of cutting down the weight of the single pieces, and also for facilitating the erection, they are made in four parts. In order to permit a ready inspection of wheels and nozzles, manholes with bolted-down covers are provided at the side of the housing.

The main bearings have shells with cylindrical support, lined with anti-friction metal. Rack-teeth cast in the outside of the bottom shell make it possible to rack it around the shaft and to remove it without the necessity of lifting the rotor and shaft out of the bearings. All that is necessary is to transfer the weight of these parts upon temporary blocks.

The governors have a pressure and vacuum tank cast with the frame; the oil pump also forms an integral part of the governor, and, like the pendulum, is belted directly to the main shaft.

It is apparent that each unit is homogeneous and independent, from the forebay to the switchboard.

Of the two exciter units (for a third one, foundation pit and pipe connections are provided) either one is sufficient to energize four of the main units. In general design they are identical with the main units, but generator, bearings and base form one element of the unit, and the water wheel was pressed upon the extended generator shaft after arrival at the plant.

Water is conveyed to the wheel by a single needle nozzle, operated directly by a Lombard hydraulic governor. The latter

is mounted upon the nozzle casting and takes its water from the main pipe line.

For the operation of solenoid switches, and to furnish direct current for various other purposes, a motor-generator-water-wheel set was installed in a chamber under the switchboard, consisting of a D. C. generator, an induction motor and a 50 h.p. water wheel equipped with a needle nozzle for hand operation.

The Transmission Line.

A double line of twenty-one miles length connects the plant with Baramulla, and from there it is continued as a single line to Srinagar (thirty-three miles).. The present voltage is 30 000.

Communications.

The old "jhula" over the Jhelum at Baniar has been replaced by a suspension bridge of permanent type, and a good light bridge of steel wire rope has also been erected just above the power station at Mohora. These have been constructed with materials that had served their purpose on the works, and are primarily intended to facilitate access to the transmission line (the vital importance of which can be hardly overstated) in this, its most difficult section. The bridges at the same time confer on the people of the locality a much-appreciated boon.

The whole of the unskilled, and a large proportion of the skilled, labor throughout has been drawn from Mohora, Srinagar, Poonch and Jammu, so that a number of the subjects of His Highness the Maharaja Sahib have derived substantial benefit in the shape of remunerative employment on these works during three years. Most of the contractors also were residents of Kashmir and Jammu. The whole work, including the erection and installation of plant, both hydraulic and electric, was practically completed on August 15, 1908.

Cost of Plant.

The cost of the entire plant to date has been about $825 000, including transmission lines and distributing system.

Contractors.

The entire electrical equipment was furnished by the General Electric Company, of Schenectady, N. Y., the entire hy-

draulic equipment by the Abner Doble Company, of San Francisco. The former was shipped from New York via Suez, the latter partly the same way, partly from San Francisco via Hongkong; the pipe lines, from Hamburg via Suez.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1911, for publication in a subsequent number of the JOURNAL.]

MANGANESE STEEL.

By F. E. Johnson, Member of the Utah Society of Engineers.

[Presented before the Society, October 21, 1910.]

Manganese steel was first successfully produced by the Hadfields in England, some thirty years ago, and was known as Hadfield steel, and was for a long time manufactured under their patents in that country. It was first made in the United States by the Taylor Iron and Steel Company, of High Bridge, N. J., this company having made arrangements which gave it the sole right of manufacture in this country. It is still producing this steel, which is known as the "Tisco steel." About five or six years ago, other foundries in this country took up its production, and they soon discovered that it was a very difficult metal to produce, and comparatively few foundries to-day are making a successful product. In fact, we can almost confine the manufacture in the United States to two foundries, the one above mentioned and the Edgar Allen American Manganese Steel Company, which was formerly the American Brake Shoe and Foundry Company. This company has two foundries, one at Chicago Heights, Ill., and the other at Newcastle, Del. Besides these two there are several other companies casting this steel, but in my travels I have never run across any other manganese steel than that manufactured by the two companies named.

For a long time the Edgar Allen Company, Limited, of England, who really are the pioneers in the production of this metal, sold in this country, but now the Edgar Allen American Manganese Steel Company, which is the consolidation of the Edgar Allen Company, Limited, and the American Brake Shoe and Foundry Company, has taken over their American business.

We might define manganese steel as a metal of the following composition:

	Per Cent.
Manganese	11.00 to 15.00
Carbon	1.00 to 1.20
Silicon	0.25 to 0.40
Phosphorus	0.06 to 0.11
Sulphur	0.02 to 0.06

Balance of analysis, iron.

However, many variations have been tried and many accidental metals have been manufactured, and this steel can be best classified as a metal high in manganese — anywhere from 8 per cent. to 35 per cent.

The two chief factors in manganese steel are manganese and carbon. One has to be very careful in its manufacture to see that the percentages of these are in the right proportion; too much carbon and not enough manganese makes the steel very stiff and brittle, therefore it does not possess the quality desired for this metal, and that is resistance to abrasive action which results from the combination of strength and ductility. There have been many mixtures experimented upon containing such ingredients as chromium, aluminium, tungsten, nickel, copper, titanium, vanadium and other metals, with some good results, especially the mixture containing chromium and vanadium, as both these metals raise the elastic limit of the steel; but at present commercial manganese steel is practically a steel containing around 10 to 15 per cent. manganese and 1 per cent. carbon, without addition of any of the above metals mentioned.

Manganese steel is considered as being a very hard metal, due to the fact that it cannot be machined as readily as other steels or chipped with a cold chisel to any great extent; in fact, it is almost a useless task to attempt to cut or drill it with even the highest quality of tool steel. Tests made on the sceleroscope scale show Bessemer rail hardness of about 30, manganese steel 40 to 50 and chilled cast iron 65 to 70, and yet it has been demonstrated many times that manganese steel will outwear either of these metals many times over. Manganese steel weighs about 0.28 lb. per cubic inch, which is slightly heavier than cast iron or low carbon steel. Specific heat ranges from 0.145 at ordinary temperatures to about 0.20 at 1 200 degrees Centigrade. The heat conductivity, though not yet determined properly, is about one third that of low carbon steel between ordinary temperature and 600 degrees Centigrade.

The electro-magnet has no effect upon manganese steel containing a certain percentage of Mn. and over, and it will not become a permanent magnet by having a current passed through it magnetizing it; hence its use for disks in magnetic cranes, as the smallest particle of iron or steel will not cling to it after the current is shut off. The steel from tests made by Mr. Potter, who was connected with the American Brake Shoe and Foundry Company, showed that it is not seriously affected by temperatures below plus 395 degrees Centigrade or above minus

190 degrees; but I question this, and a great many engineers and master mechanics believe manganese steel can be heated, and even forged. Manganese steel such as I am familiar with cannot, and I will read you a circular letter which the Edgar Allen American Manganese Steel Company send out:

"In order to avoid loss and inconvenience to both our customers and ourselves, we wish to strongly impress upon the minds of all our customers that manganese steel castings should never be heated, as castings of plain design, although heated to but 400 degrees Fahrenheit, will lose toughness and strength to a remarkable degree, while castings of irregular design will stand even much less heat than 400 degrees above mentioned. In fact, a casting such as roll shell, which is cylindrical in shape, while free from internal strain stress at the time it leaves our works, will, upon being heated, very likely break or crack, showing plainly that the application of heat has resulted in setting up an internal strain in the casting.

"We cannot express ourselves too strongly in this connection, and you will readily appreciate our position when we say that we cannot be responsible for the breakage of any manganese steel castings which have been heated after their shipment from our works."

This letter particularly refers to heating such castings where it is desired to cause a shrinkage or contraction in order to secure the casting more firmly in its position, such as roll shells, on their centers or cores, either in cases where taper centers are used or they are zinced on. To give you some idea of the strain caused, one instance will be cited. The Utah Copper Company put its shells on the centers by means of zinc poured in between the shells and centers, first heating the shell to slightly expand same, so that when it cooled it would become tight on its center. Recently they received four manganese steel shells to test. They were not cautioned regarding heating, so they put these shells on the centers by the method mentioned and two of them cracked. The shells are $4\frac{1}{2}$ in. thick, 15 in. face and $37\frac{1}{2}$ in. O. D. One shell cracked at one place and one at two places, all cracks running very nearly across the full face of the shells and clear through the $4\frac{1}{2}$-in. thickness. Sometimes the fracturing will not take place for as long as six weeks after they are put on.

This steel melts around 1 330 degrees Centigrade. The coefficient of friction of manganese steel is somewhere around eighteen per cent. Tensile strength early determined by Mr. Hadfield is about 150 000 lb. per square inch, with an elongation as high as 50 per cent. This, however, is higher than the average commercial steel being cast to-day, which runs about 82 000 lb.

tensile strength, elongation 30 per cent. with an elastic limit of 45 000 lb. However, forged manganese steel will run higher, but there is very little commercial forged manganese steel being made at this time.

The greatest characteristic of manganese steel is its resistance to abrasive wearing action, which is due to its ability to flow or endure repeated distortion of its wearing surface. One might say that it does not easily wear off, due to the fact that it will simply wear at one place and build up at another, and thereby it keeps up a sort of an endless reconstruction. You can take a square corner of a piece of manganese steel and peen it over and then pound it back to a square corner, and keep up this operation, and find that there will be veiy little loss in weight.

We will now take up the manufacture of this steel, which, however, I know very little about, because manganese steel is manufactured with a great degree of secrecy. Though I have spent several days at the foundries, all that I learned was what I could see for myself. The steel is composed chiefly of a mixture of scrap iron and pig, this mixture being very carefully made up according to analysis. This is melted in an ordinary cupola, such as any foundry uses, and is then run into a converter and blown quite similarly to Bessemer steel. This process, however, is very delicate and is attended to by one man only, who operates everything from the central station or platform close to the converters. After it is blown it is poured into large ladles from which the slag is removed, and the manganese, which has previously been melted in graphite crucibles under very intense heat, is then added. From these large ladles it is poured into sand molds which are practically the same as ordinary cast-iron molds. The main thing to take care of is the excessive shrinkage when cooling, as manganese steel shrinks five sixteenths of an inch per foot while ordinary cast iron only shrinks one tenth of an inch per foot. Also in the manufacture of manganese steel there has to be cast into the castings very often soft steel bushings and inserts wherever it is necessary to bore out, drill or tap the casting for finishing, such as hubs of car wheels, crane wheels, cutting of key seats, putting in set screws, etc.; and you can see that the casting in of these inserts is quite a difficult task, because they must not only be in their proper position, but must be so cast in that they will not work loose — and this with the excessive shrinkage makes it very difficult to get a satisfactory casting.

All ladles and molds are kept very hot, so as not to chill the metal before it is poured, as it is absolutely necessary to have a

homogeneous casting free from all blowholes and other defects, because manganese steel castings are used where great strains and shocks are experienced.

So far the manufacture is quite simple, but the difficult part now comes, as all castings are treated either by heat treatment or both heat treatment and water submergence. This part I know nothing about, but I know that this after-treatment gives the toughness to the metal, for before treatment it is quite brittle but very hard.

Manganese steel castings can only be successfully made to certain sizes as to lengths and particularly area of cross-sections, where the thickness is a prime factor. The greatest thickness of any section that has been successfully cast up to date is about $4\frac{1}{2}$ inches. I have seen 5-in. roll shells, but they did not wear so well. It is also very difficult to cast in small or thin sections, the limit being about $\frac{3}{8}$ in. thick for ordinary castings such as car wheels, small lining plates, etc.

The reason why the thickness is so important is owing to the after-treatment, which will only penetrate to a certain depth, and the thinness is regulated by the flow of the metal.

After the castings are taken from the molds and treated, they are removed either to the grinding shed or machine shop, where all finishing work is done. In cases of castings where no finish work is required, they are simply rough finished by means of carborundum wheels attached to movable or swinging frames, on which is also mounted an electric motor for driving the wheel. This arrangement is for grinding large and heavy castings. For small castings the regular grinder stand is used, and in cases where it is necessary to get into corners the wheel is connected to the motor by a flexible shaft.

In the machine shop the planer, lathes, etc., are equipped with carborundum wheels whenever the finish has to be done out of the manganese steel itself. However, in cases of soft-steel bushings and inserts, the work is done by the usual machine-shop practice.

The smallest hole that can be finished or ground out of the manganese steel is about 2-in. diameter, but this very seldom has to be done, as in very nearly all cases where castings have to be machined for shafts, pins and key seats it can be done by putting in soft-steel bushings. Coring the castings is resorted to as much as possible so as to save in cost of manufacture.

In case of roll shells, for instance, where they are put on the centers by means of taper cores, they have to be finished inside

diameter, and that necessitates a great deal of work because the finishing has to be done on the manganese steel itself, and it will take a first-class grinder about three days to finish up one shell of 36-in. diameter by 15-in. face.

The uses for manganese steel are not very extensive at present, due partly to its high first cost, and the difficulty of machining it. However, this steel is now used for castings which are subjected to very heavy strains and shocks, and excessive wear, such as wearing parts for gold dredges, steam shovels, ore and rock crushers, crushing rolls, dry pans, etc.

It is also being used for tube mill liners, komminutor plates for cement mills, gear wheels, sprocket wheels, sheave wheels, trommel screen plates, tires and bearing wheels for trommels or revolving screens, and a great many other castings of similar nature. Manganese steel is also being rolled and forged, this usage being practically confined to railroad rails, and some flats and rounds. The flats are usually made up into bushings, principally for links used in connection with the gold dredges.

In order to give some comparison of the wearing value of manganese steel and chilled cast iron I will give the results of a recent test made by the Anaconda Copper Mining Company at Anaconda. I will first give you the test made in a 24 by 12 Blake crusher using two sets of manganese steel-jaw plates.

Date Put In.	Date Taken Out.	Tons Crushed.
April 16/10	June 4/10	54 140
April 23/10	June 15/10	57 853

The chilled cast-iron plates crush on the average of 16 000 tons before taken out.

The manganese steel plates in their 5 by 15 crushers average five to six times longer than the chilled cast-iron plates, which is quite a little better than the average for the 12 by 24 crushers.

They also made tests in their trommel screens. A set of manganese steel plates were put in December 3 and taken out June 19 and handled 209 262 tons of ore. The average life of cast-iron plates in the screen is thirty days, or 33 000 tons of ore; so you will see from this that manganese steel wore between six and seven times as long. The Anaconda Copper Mining Company has manganese steel crane wheels which have been in service two years and show very little wear. It is safe to say that manganese steel will generally wear from four to eight times as long as chilled cast iron, depending for what purpose it is used and the condition under which it works.

Manganese steel has made it possible to cut down the maintenance cost very materially for many machines. Take, for instance, the steam shovel. There are used on the dipper, teeth which have until recently been made from solid forgings, and by being able to cast a metal of the toughness of manganese steel it is possible to make these teeth, generally in two parts, known as the Panama tooth, and thereby it is only necessary to renew the points, the bases lasting almost indefinitely. This is not only a saving in the material, owing to the small amount of scrap thrown away, but is a great saving of time and labor in renewing the teeth, as it saves all cutting of rivets and of damaging the dipper itself, and the re-riveting of the new teeth on to the dipper, because all one has to do to renew the Panama tooth is to take out one or two bolts which hold the point on to the base, and the operation of renewing a set of points only requires about twenty minutes' time.

They also are making segmental gyratory crusher heads and segmental roll shells which are proving very successful and economical.

Before you on the table are several manganese steel castings. This one is a point of a two-part or Panama dipper tooth. We have also a portion of a dipper handle rack used on shovels, and a shipper shaft pinion for steam shovels, and a mine car wheel with hub of soft steel bushed. You can easily see the marks left by the carborundum wheels, and these castings are all rough finished.

On the board is sketched an outline of a dredge boat bucket bottom, and I wish to give you some idea of the toughness of this steel. This casting was placed on its side and a 2 540-lb. drop weight applied to the lugs as follows:

1 drop, height 5 ft., deflection between lugs 0 in.
1 drop, height 6 ft., deflection between lugs $\frac{1}{8}$ in.
1 drop, height 7 ft., deflection between lugs $\frac{1}{8}$ in.
1 drop, height 8 ft., deflection between lugs $\frac{1}{4}$ in.
1 drop, height 10 ft., deflection between lugs $\frac{1}{4}$ in.
1 drop, height 14 ft., deflection between lugs $\frac{3}{8}$ in.
1 drop, height 20 ft., deflection between lugs $\frac{1}{2}$ in.
41 drops, height 23 ft., deflection between lugs $3\frac{1}{2}$ in.

The original distance between lugs was $15\frac{1}{2}$ in. After test it measured 12 in.

This is a cast straight bar of manganese steel $\frac{3}{4}$ in. wide by $\frac{1}{2}$ in. thick, and here is a duplicate bar bent cold. What other metal gives you such wearing qualities with such strength?

I have not touched on manganese steel for railway work, as I am going to leave that side of it for Mr. Tempest to discuss, but before closing, I wish to correct an idea which prevails among railway engineers that this steel will not stand shocks. I have here a cut of a solid manganese steel frog which weighs 800 lb., and which was bent under a drop weight for test for the Indianapolis Switch and Frog Company of Springfield, Ohio, and was on exhibition last March at the convention of the Maintenance of Way Association, and caused no little comment. This frog was subjected to 165 drops of a 1 250- and 2 500-lb. weight for a distance ranging from 3 to 23 ft., aggregating 1 679 375 ft.-lb., yet shows no fracture or impairment of any nature.

Here are some recent photos of a four-section solid manganese steel crossing in use by the Chesapeake & Ohio Railroad at Roswell, Va. This is a photo of a solid manganese steel crossing used by the Chicago Street Railway.

There are hundreds of solid manganese steel frogs and cross-overs now in use. The new Northwestern Terminal in Chicago has some two hundred frogs installed, so you can see manganese steel is entering very rapidly into modern railway construction.

DISCUSSION.

Manganese Steel in Use in Railway Trackwork.

Mr. J. R. Tempest. — Manganese steel was first used in track work about 1894. Its use has been gradually increasing, until at the present time practically all street railway companies, with heavy traffic, are installing specials of either solid manganese or with hard centers. It is also in use on many steam roads where the traffic is very heavy, as it eliminates the frequent replacing of the common steel-rail specials.

The types of manganese specials as mentioned before are solid manganese and hard-center work. The solid manganese type consists of solid manganese castings. In this class the traffic surfaces are ground to smooth finish and line, and the ends are ground to fit the plates of adjoining rails. This is the highest class and gives the most service. The hard center work consists of cast-steel or cast-iron bodies, with pieces of rolled rail, of the section desired, cast into the bodies, and a manganese steel center plate inserted in body. The insert plate is set where it will take the greatest wear that comes on the special. These plates are generally made so that they can be renewed. This is usually

unnecessary as far as wear is concerned, but they sometimes work loose and need tightening. The above is especially true where the small square insert is used in the 90-degree or square crossings.

In addition to the use of manganese steel in specials, it is used by a few roads for rails on their sharp curves where common steel rails last only a short time. These rails are very expensive for first cost, as they are cast in lengths up to twenty feet, but this feature is soon offset by the wearing quality. For comparison, the manganese rail was installed in a curve on the Boston Subway and after twenty-four hundred days' usage, the rail was still in serviceable condition, with a wear of five eighths of an inch. Previous to the installation, it had been necessary to change the Bessemer steel rail every forty-five days, after wear of about seven eighths of an inch. This shows a ratio of service of fifty-four to one, with a large saving in the labor of changing rail.

For comparison of service of hard center crossings with the common built-up crossings, the records of two installed on the Pennsylvania Railroad main line show that at a point where it had been necessary to change ordinary crossings every three months, the manganese center crossing was still in service after seven years.

In testing the hardness of a manganese switch tongue, a ½-in. Morse twist drill was used for a period of two minutes, resharpened and the same operation repeated four times, with no perceptible effect on the metal. This shows that the manganese steel is practically undrillable.

The above comparisons have been taken from records on other roads, as the work installed on the Utah Light and Railway tracks has not been in service long enough to show any great amount of wear. The only repairs we have found necessary have been the straightening of a few switch tongues and the tightening of the centers in the square crossings.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1911, for publication in a subsequent number of the JOURNAL.]

OBITUARIES.

Beriah Warren.

MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

BERIAH WARREN was born May 21, 1830, in Denmark, Oxford County, near the southwestern border of Maine, and died in St. Louis, Mo., August 16, 1910, aged eighty years and two months, leaving surviving him two sons and five daughters.

He was the son of John McIntire Warren (born in Fryeburg, Me., August 25, 1798; died September 20, 1840) and Hannah Swan Warren (born Bethel, Me., April 7, 1793; died April 27, 1881).

After the ordinary schooling of the time, we find young Warren working as a house carpenter at Fryeburg, Me., near his home, and then as a pattern maker in Lowell, Mass. In 1852, at the age of twenty-two, he accepted a position as pattern maker and carbuilder with the Marietta & Cincinnati Railroad, then under construction and now a part of the Baltimore & Ohio Southwestern Railroad. His headquarters were at Chillicothe, Ohio, to which place he came by canal boat from Cleveland, to which point, in turn, he had come by steamer from Buffalo — the present railroads between these points being then unbuilt. During his residence here, in 1855, at the age of twenty-five, he was married to Margaret Jane Eagleson (born April 7, 1832, in Athens, Ohio; died July 4, 1904, in St. Louis, Mo.). After six years in Chillicothe, he came in 1858 to East St. Louis to work as pattern maker for the Ohio & Mississippi Railroad, now part of the Baltimore & Ohio Southwestern system, but in 1859 was called back to his former position in Chillicothe.

In 1860 he returned to East St. Louis, this time as foreman of the shops of the St. Louis, Alton & Terre Haute Railroad, of which railroad his friend Henry C. Moore, past president of the Engineers' Club of St. Louis, was then superintendent. After four years' service in East St. Louis, Mr. Warren was promoted to the position of master mechanic and superintendent of the Car Department of the same road, with headquarters at Litchfield, Ill. After four years at Litchfield, Ill., he was, in 1868, appointed superintendent of machinery of the Pacific Railroad of Missouri, with headquarters at St. Louis. Two years later, in 1870, he became superintendent of machinery and general

superintendent of the Cairo Short Line Division of the St. Louis, Alton & Terre Haute Railroad (now part of the Illinois Central Railroad) — his residence remaining in St. Louis. After twelve years in this position, he went, in 1882, to Indianapolis as general master mechanic of the Indianapolis, Bloomington & Western Railroad, now one of the New York Central lines.

From 1885 to 1900 he was superintendent of machinery and purchasing agent of the Toledo, Peoria & Western Railroad, with headquarters at Peoria, Ill.

In 1900 he returned to St. Louis, intending to retire from active life. Very soon, however, he was called upon to act as general superintendent of the St. Louis, Troy & Eastern Railroad, a position which he held until 1905, when, at the age of seventy-five, after fifty-three years of railroad service, he finally retired.

Mr. Warren was a member of the Engineers' Club from November 6, 1878, until his death, a period of nearly thirty-two years.

As a mechanic, Mr. Warren ranked high. In the movement toward freight cars of large capacity he was a leader, one of the first cars of 60 000 lb. capacity having been built at Litchfield by him. As an executive officer he was kindly but decisive and firm — a man with whom no one could trifle. Above all, he was a man of high standards, who shirked no duty, and who in every relation in life was absolutely trustworthy. He was always a positive force on the right side, and he leaves a memory to be long cherished by all who knew him.

Philip Florreich, Jr.

Member of the Engineers' Club of St. Louis.

(Memoir prepared by J. W. Woermann, U. S. Assistant Engineer.)

Philip Florreich, Jr., was born in St. Louis, Mo., April 5, 1875. He received his early education in the public schools of that city. In 1890 he entered the School of Mines of the University of Missouri at Rolla, and after two years of preparatory work and three years of technical work was graduated with the degree of Bachelor of Science in Civil Engineering in 1895.

For nearly three years after graduation he served as chemist and bookkeeper for the Standard Vinegar Company and Erley & Bauer of St. Louis. In 1897 he examined and reported on mining properties for the late Col. Henry Flad.

In 1898, at the beginning of the Spanish-American War, he enlisted in Company H, First Missouri Volunteers, and was honorably discharged without having seen service outside of the United States.

From April, 1899, to April, 1901, he was employed on Mississippi River improvement under the United States Engineer Office at St. Louis, Mo.; during field seasons, as an observer on triangulation, topography, hydrography, leveling, borings and discharge observations; during the winter seasons, on maps, computations and the compilation of physical data.

From April to October, 1901, he was engaged in making surveys and maps for the purpose of determining the best location for the Thebes railroad bridge across the Mississippi River. From October, 1901, to June, 1902, he was employed by the Missouri Pacific Railway in making surveys, maps and reports on railroad location and special bridge and right-of-way questions. From June to August, 1902, he was engaged on land and city surveying in St. Louis County, Missouri.

From August, 1902, to October, 1907, he was again employed on the improvement of the Mississippi River between St. Louis and Cairo, — during this period with the rank of United States junior engineer. His work was similar to that previously described, and in addition he was engaged during a portion of the time on plans and specifications for dredges and other floating plant.

From October, 1907, to April, 1909, he was engaged in making surveys, maps and estimates, and in the compilation of physical data in connection with the project for a fourteen-foot waterway from St. Louis to Cairo. His most important work under this assignment was the making of 117 borings to bedrock in the bed of the Mississippi River, and the supervising of borings made by contract in the alluvial valley adjacent thereto. The average depth of the borings exceeded one hundred feet. He is entitled to much credit for the ability and ingenuity displayed in completing many of these borings under very difficult conditions.

In February, 1909, Capt. G. R. Lukesh, Corps of Engineers, U. S. A., in recommending him for promotion to the rank of United States assistant engineer, reported officially that " . . . as chief of one of four large survey parties, his methods both in organization and administration have been excellent; the field work, the making of a large number of test borings for determining bedrock and overlying strata in the alluvial valley between

St. Louis and Cairo, was characterized by unusual ability in prosecuting the work of his own party and supervising the making of borings under contract. Since the completion of this active work he has been engaged in office reduction of notes pertaining to the boring survey, and has had assigned to him various important matters in connection with the compilation of data for the report of the board, involving investigations and computations, drawings, tabulating all permanent marks in the stretch surveyed and other incidental work of value." He was promoted to the rank of United States assistant engineer on March 1, 1909.

From April, 1909, to the time of his death he was again employed on river improvement between St. Louis and Cairo.

Although his health had not been good for some time, his death was an unexpected shock to all who knew him. On September 16, 1910, he was in the field all day with his party near Chester, Ill.; on September 17 he was taken to St. Louis in an unconscious condition, suffering with a high fever, and died on September 18.

Mr. Florreich was a Scottish Rite Mason of the thirty-second degree, and was buried with Masonic honors, his associates from the United States Engineer Office acting as pallbearers.

His German extraction is shown in the carefulness and thoroughness with which he carried out all of his work. He believed in doing his work thoroughly for the sake of having it right. The files of government maps and reports which bear his name in the United States Engineer Office at St. Louis constitute a permanent memorial to his conscientious work in the field and in the office.

Mr. Florreich was married, on June 30, 1908, to Henrietta Norrish, of St. Louis. He is survived by his wife and one brother.

Mr. Florreich was a man of versatile talents and wide interests. His range of scientific knowledge was unusually large, particularly in physics, chemistry, geology and botany. As an illustration of this it may be mentioned that in his garden at Webster Groves he cultivated more than sixty varieties of dahlias, in addition to many varieties of sweet peas, roses and other blossoms.

Mr. Florreich was a young man of sterling qualities and high ideals; of unobtrusive manner and unpretentious ways. His life was clean and honorable, his disposition sweet and lovable. His untimely death is a keen loss, not only to his family, to whom he was most deeply devoted, but to his many friends, to his profession, and to his country, — which he served so faithfully for so many years.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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METHODS AND COSTS OF CONSTRUCTION OF THE SLOW SAND PURIFICATION WORKS FOR THE NEW SPRINGFIELD, MASS., WATER SUPPLY.

BY CHAS. R. GOW, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, November 16, 1910.]

THE city of Springfield, Mass., has, within the past year, completed and put into operation an entire new water supply system, embracing among other features a purification plant located near the source of supply in Westfield. It is the purpose of this paper to describe in detail the methods and costs of constructing the several works comprising the purification plant. This work was carried on under the supervision of the Water Commission of the city of Springfield, for whom Mr. E. E. Lochridge was chief engineer, Mr. Allen Hazen consulting engineer and Mr. H. M. King resident engineer. The writer served in the capacity of contractor for the purification plant.

No claim is made in this paper for novelty of methods used nor for any special economy in costs, the writer's intention being to merely present a statement of the actual problems, the conditions governing same and the results obtained. With the feeling that more knowledge is to be gained from the study of failures than of successes, it is his intention to point out the mistakes made as freely as the commendable features, and to suggest possible improvements which might in a future similar case increase efficiency or reduce costs.

An idea of the features embraced in this contract can be obtained from a study of Fig. 1, which shows in general plan the relative locations of the several parts of the works.

Raw water from the river, after arriving through a tunnel built under a previous contract, is carried by the 54-in. steel pipe shown at the left, which later reduces to 42 in. to the settling basin, passing under the earth dam which impounds the water of the basin, entering a reinforced concrete conduit 4 ft. by 5 ft., by means of which it is finally discharged into the upper end of the basin.

The settling or sedimentation basin is of approximately ten acres in area at spillway level and contains, when full, 40 000 000 gal. Its location is a natural recess in the surrounding hills, which required only the clearing and grubbing of the surface and the construction of an earthen dike as shown to be transformed into a suitable reservoir. The main purpose of this basin is the natural removal by sedimentation of such suspended matter as may be contained in the river water, thus relieving the filters of these solids to a large extent.

The water, after settling, passes by means of a second 42-in. steel pipe outlet through the earth dam to the office and laboratory building, where are located certain regulating devices and hydraulic apparatus, and from there to the aërator, an open circular concrete tank 50 ft. in diameter, where aëration may be effected if desired by fountain action. The water level of the aërator is adjusted to regulate that in the filters, and water is distributed from this point to the filters by means of a 30-in. cast-iron header pipe connected by independent 16-in. connections to each filter.

The filters are of the slow sand type and six in number, each unit covering 0.52 acres and yielding one-half acre net sand area. Fig. 2 illustrates the relative location and dimensions of the filters, together with the arrangement of piping, while Fig. 3 illustrates the details of concrete construction. The pure water is collected in 24-in. drains laid under each filter and conducted in independent pipes to the regulator house, from which it enters the 42-in. steel main to the city.

The contract for this work, as let, covered 28 different items of work upon which unit prices were obtained. Seventeen bidders submitted proposals, the totals of the various bids ranging from a minimum of $201 525 to a maximum of $293 752, with an average bid of $250 108. The contract was awarded and signed March 31, 1908, and provided that the work should be completed on or before October 1, 1909, or in two working seasons. Work was begun on April 6, 1908, and the contract finally completed November 17, 1909, forty-eight days overtime.

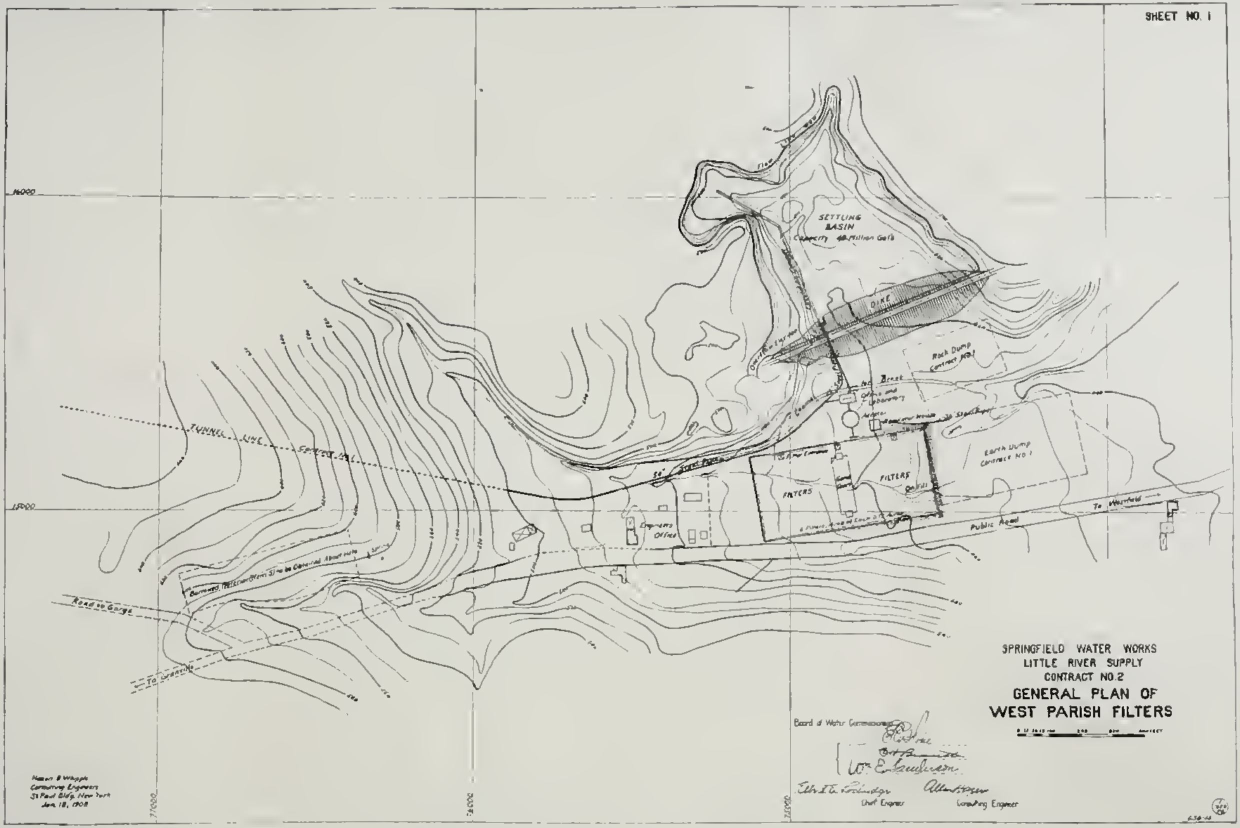


FIG. 1. GENERAL PLAN OF PURIFICATION WORKS.

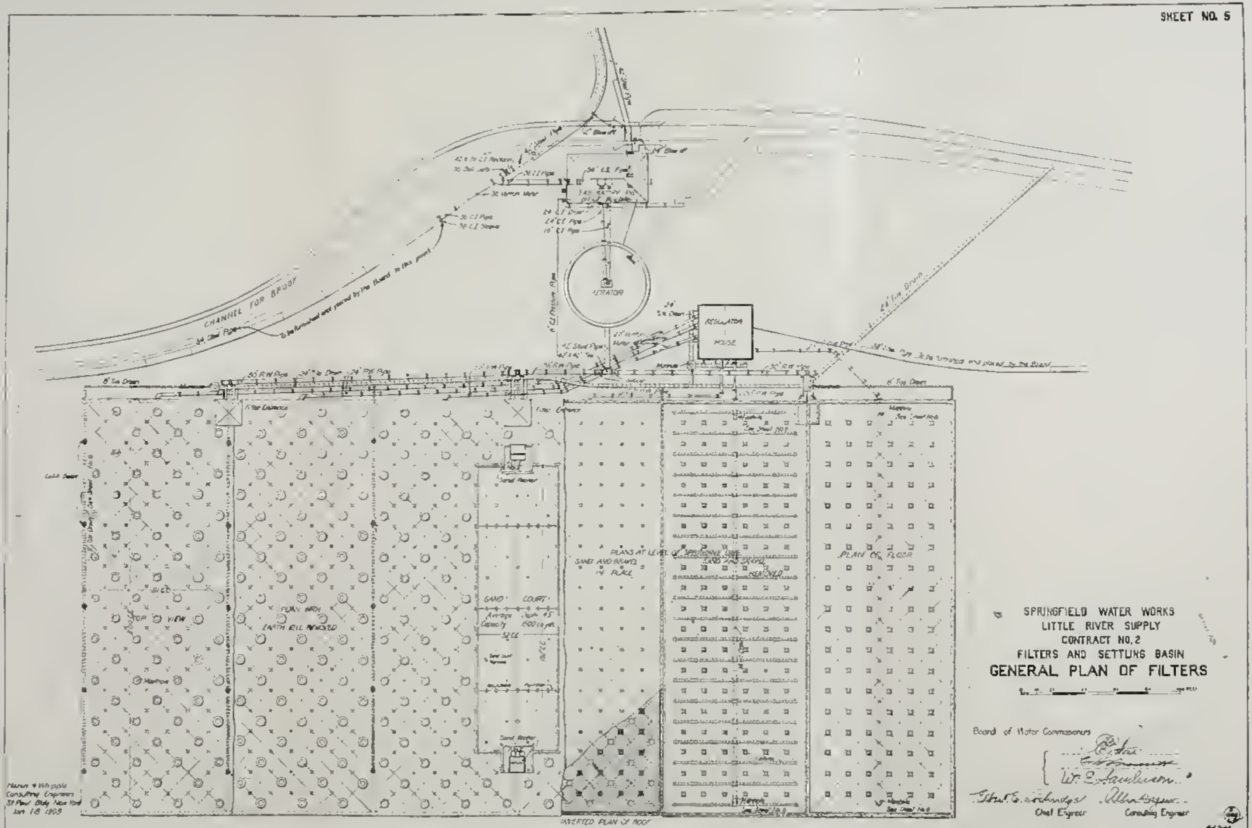


FIG. 2. GENERAL PLAN OF FILTERS.

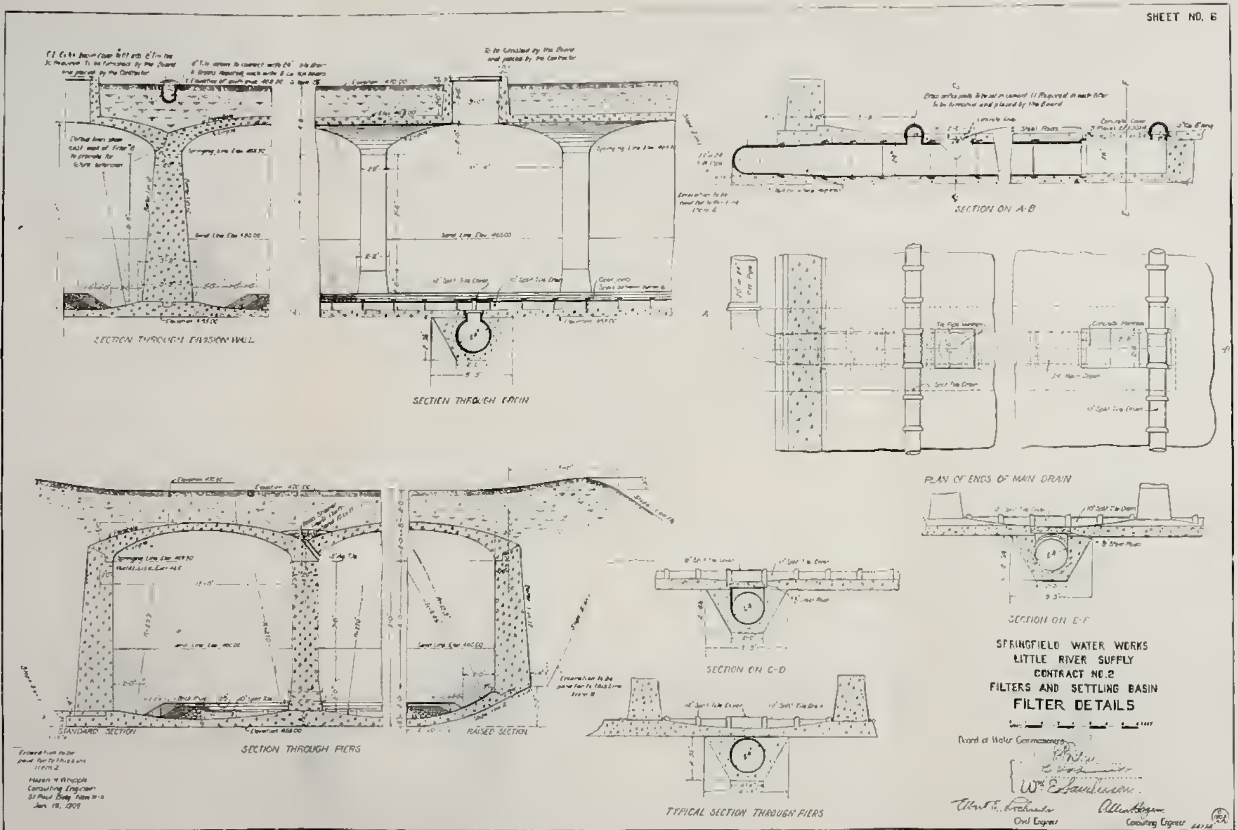


Fig. 3. Details of Filter Construction.

To avoid confusion, the various features of interest will be considered and treated as independent subjects in the descriptions which follow. All cost figures shown include every expense chargeable to the item either directly or indirectly except interest on invested capital and the proportion of main office expenses.

Cost-Keeping System.

A new system of cost keeping was originated and introduced on this work by the writer and gave such satisfactory results as to warrant, in his opinion, a brief description here.

The various items of work embraced by the contract were numbered from 1 to 28, corresponding to the several classifications upon which unit prices were bid. Thus, Grubbing No. 1, General Excavation No. 2, Trench Excavation No. 3, etc. In addition to the twenty-eight main headings, a number 0 was added to cover the General Expense item, to which was charged such expenses as could not from their general nature be charged directly to any individual classification of work. Owing to the fact that items 13, 14 and 15 referred to three different classes of concrete masonry, it became necessary to introduce item 29, to which was charged all general concrete expenses such as plant erection, preparation of stock, etc., which could not be divided daily between the three classes. The third extra item, No. 30, was introduced to cover the stable account by means of which the unit cost of teams was ultimately determined. These three extra items were, of course, finally divided, in proper proportion, among such of the twenty-eight main items as were affected by them.

Having thus designated each main item from 0 to 30, the various subdivisions required were referred to alphabetically, 1-*a*, 1-*b*, 1-*c*, etc. Thus, when it was desired to subdivide General Excavation, 2-*a* referred to hand excavation, 2-*b* to steam shovel excavation, 2-*c* to teaming excavated material, etc. In case it was desired to subdivide a subdivision, recourse was had to a numerical suffix such as a^1, b^1, a^2, b^2. Thus, for example, while item 2 referred to General Excavation and 2-*c* to teaming General Excavation, 2-c^1 referred to teaming from steam shovel and 2-c^2 referred to teaming from hand excavation. By introducing c^3, an additional division of teaming could be kept if desired, and so on. The main numerals were easily remembered since they referred in each case to the contract item of that number. The alphabetical designations and their suffixes soon became familiar to the user, inasmuch as they were added to the list gradually as

the work progressed, and only a comparatively few headings were in use at any one time.

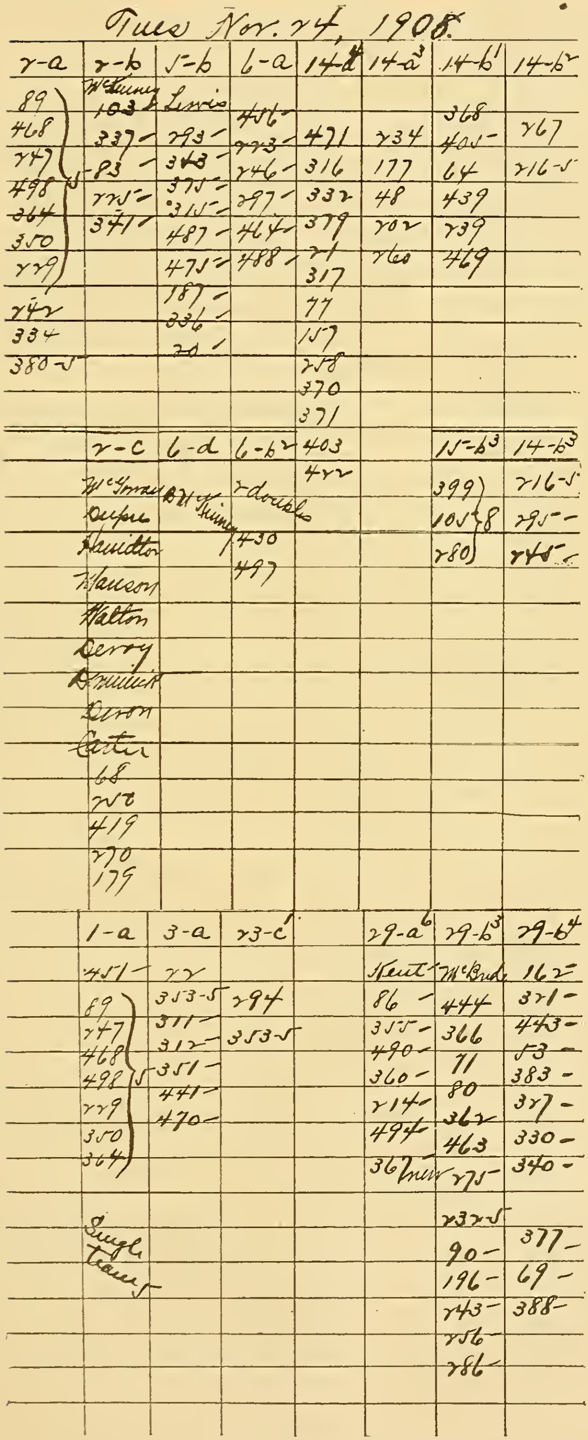
The following table shows the division of the General Excavation item and is typical of the method employed:

Item 2, General Excavation.	*a*. Hand excavation.	a^1. Labor.
		a^2. Materials.
	b. Steam shovel excavation.	b^1. Labor operating.
		b^2. Fuel and oil.
		b^3. Labor repairing.
		b^4. Materials repairing.
		b^5. Labor moving to work.
		b^6. Materials installing.
	c. Teaming.	c^1. From shovel.
		c^2. From hand excavation.
	d. Foremen.	

It will be readily seen that there is no limit to the possible elasticity of this system of subdividing. It should be borne in mind, however, that attempts at too fine a subdivision not only entail much additional clerical work, but also invite inaccuracies. The divisions adopted were deemed sufficiently fine for the purpose of showing the relative costs of each important item of expense. If it was desired to ascertain the cost of some small feature of an item, the expenses chargeable to the feature were temporarily detached from their natural parent subdivision and given an alphabetical or numerical designation of their own. When the desired information had been obtained, the temporary division was again merged with its parent division and its cost consolidated with it.

The timekeeper, on making his first morning trip, entered on a convenient pocket-pad the various numerical and alphabetical designations of the different kinds of work he found in progress, and under each such heading the names or numbers of the men he found employed thereon. On his subsequent trips he checked this list, and if changes had occurred ascertained from the foreman the time of such changes. In this manner, at the close of each day his pad showed under the separate headings what men had worked under each division of labor during the day and for how many hours each had so worked. Fig. 4 shows a sample page from the timekeeper's field pad.

A large office time-book, made especially for the purpose,



Tues Nov. 24, 1908.

2-a	2-b	5-b	6-a	14-a	14-a³	14-b¹	14-b²
89	McKinney 103	Lewis	456			368	
468	337	293	223	471	234	405	267
247	83	343	246	316	177	64	216-5
498	225	375	297	332	48	439	
364	341	315	464	379	202	239	
350		487	488	21	260	469	
229		475		317			
242		187		77			
334		336		157			
380-5		20		258			
				370			
				371			

	2-c	6-d	6-b²	14-a		15-b³	14-b³
				403			
				422			
	McGinnis	Bill Kinney	2 double			399	216-5
	Dupree					105	295
	Hamilton		430			280	245
	Hanson		497				
	Walton						
	Perry						
	Dominick						
	Dixon						
	Carter						
	68						
	250						
	419						
	270						
	179						

	1-a	3-a	23-c¹		29-a⁶	29-b³	29-b⁴
	451	22			Kent	McBride	162
	89	353-5	294		86	444	321
	247	311	353-5		355	366	443
	468	312			490	71	53
	498	351			360	80	383
	229	441			214	362	327
	350	470			494	463	330
	364				367 new	275	340
	Single team 5					2325	
						90	377
						196	69
						243	388
						256	
						286	

FIG. 4. SAMPLE SHEET FROM FIELD PAD.

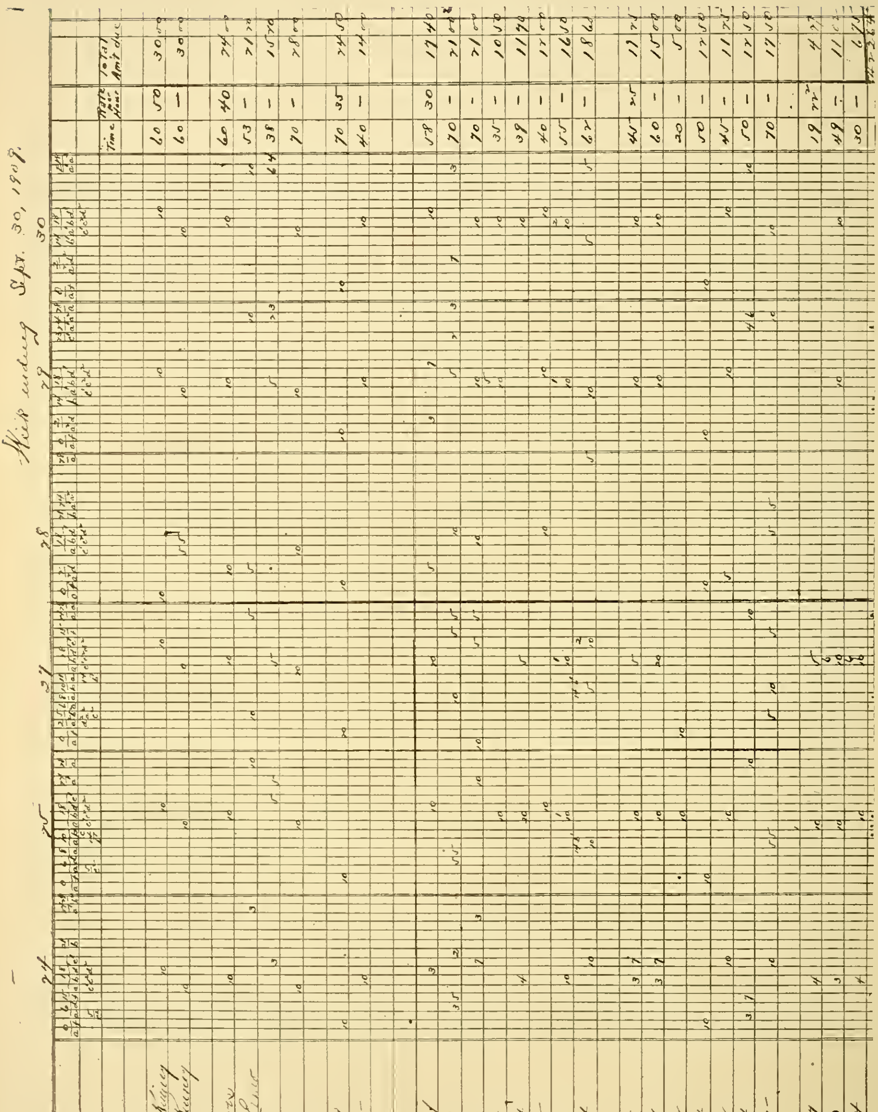


Fig. 5. Sample Sheet from Time Book.

CHARLES R. GOW COMPANY, CONTRACTORS.

DAILY FORCE ACCOUNT for *Day* Shift, *Sept. 22 1909*

Work for *City of Springfield* at *Ludlow Mass.*

CONTRACT NO *165*

	UNIT	AMOUNT	LABOR—Rates and Amounts											TEAMS			TOTAL
			60	50	40	35	30	25	22½	20	17½			35	60		
0 a			10 6.00			10 3.50											9.50
0 f								10 2.50			10 1.75						4.75
5 a^2					10 4.00												4.00
5 b^2										30 6.00	70 12.75						18.75
5 c^2															77 46.70		46.70
6 a										30 6.00	40 7.00						13.00
6 d							7 2.10										2.10
10 a							10 3.00										3.00
10 b							3 .90				20 3.50						4.40
11 - a							10 3.00	10 2.50		10 2.00	10 1.75						9.25
14 - b'								10 2.50									2.50
18 a'				10 5.00	10 4.00					31 6.20	90 15.75						30.95
18 b					10 4.00	10 3.50	31 9.30	10 2.50	30 6.75	84 16.80	87 15.22						58.07
18 c'															300 180.00		180.00
18 c^2															80 48.00		48.00
18 d'				10 5.00			10 3.00			40 8.00	60 10.50						26.50
18 d^2														66 23.10			23.10
18 e'					4 1.60			4 1.00									2.60
21 - b							10 3.00			10 2.00	20 3.50						8.50
29 - a^8					6 2.40			6 1.50									3.90
																TOTAL	498.07

REMARKS.

H B Robinson Timekeeper.

FIG. 6. SAMPLE SHEET FROM FORCE ACCOUNT.

was employed, and the time was transferred to it daily from the field pad. This book was so ruled that the width of the vertical space allotted to each day of the week was sufficient to permit of its being ruled into several narrow vertical columns. These columns were headed by inserting the various designations of the different classes of work carried on during that day. The men's names or numbers were grouped on the pages of this book according to their rates of pay, and a sufficient number of lines

was left between groups to permit the insertion of different names or numbers of new men who might commence work in the middle of the week. In posting from the field pad to this time-book, the timekeeper considered one heading at a time and gave each man who had been employed under it during the day credit for the number of hours he was so employed. In this manner, if a man had been employed under several different divisions of work during the day, his name or number appeared under each on the field pad and due credit was given in the proper columns opposite his name for the number of hours he had worked under such division. Fig. 5 shows a sample page from this time-book. It will be noticed that this book served the double purpose of a time-book, and a division of labor record.

When the time-book had been posted for the day, a daily labor force account was drawn off by adding in the time-book the number of hours which had been entered under each heading for the day. As the names were grouped together in the time-book according to the rates, i. e., all names of men receiving similar rates of pay being carried on the same page or pages, the total number of hours at each rate chargeable to any given division could be readily obtained by adding the proper column in the time-book, and the sums so obtained, when multiplied by the proper hourly rate, gave the money value of labor expended on that particular item for the day. Fig. 6 illustrates a typical daily labor-force account and shows the method of transferring from the time-book and of final consolidation, the grand total of the sheet representing the total expense for labor and teams on the whole work for this particular day. It further shows that there had been expended for the day $9.50 on 0-*a* (General Expense, miscellaneous labor), $46.20 on 5-$c^2$ (teaming from borrow), etc. These figures were then transferred to a card system kept for the purpose, there being a separate card for each division or subdivision. A daily entry was made on each card of the amount shown by the labor sheet to be chargeable to it, and the total of such entries was carried forward so that at a glance the total cost of labor and teaming to date could be ascertained for any division. A similar card system was kept for materials, each invoice being marked by the receiving clerk to indicate which division or subdivision it was chargeable to, and a corresponding entry was made on the proper card. Every expense incurred on the work, therefore, whether for labor or materials, was posted somewhere in these two card systems and frequent checks were applied to prove their accuracy by comparison with the total of the office

ledger. Approximate daily estimates were made of the quantity of work done under the several classifications, and unit labor cost prices were noted. An accurate estimate of quantities was obtained monthly and a report made of the unit cost for the month. With this system but one man was necessary to attend to the timekeeping and clerical work involved.

General Expense.

In the description and costs which follow, frequent reference is made to the item of General Expense, and a brief explanation of its meaning and application may not be out of place at this time.

In all attempts to apportion daily expense among the several items of work, it is found that many of the charges cannot be debited directly to any individual item or items. Thus, for example, the various preliminary expenses before actually beginning operations, all time of the superintendent, timekeeper, watchman, water boy, etc., are impossible of accurate division among the items as the work progresses. On this work, all expenses which were of such a nature that they applied to the entire work and could not, therefore, be charged directly to some one or more items, were charged to a General Expense account. The following table shows the detail of expenses making up this account on this contract:

Cost of General Expense Items.

				Per Cent. of Contract.
a. Supt. and miscel. general labor . . .		$7 190.67		
Teams on general work		975.54		
Miscel. small supplies		2 054.28		
Total general charges			$10 220.49	5.5
b. Insurance, employees only			1 704.19	0.9
c. General Plant.				
Shipping, labor loading .	$229.45			
Shipping, teams loading.	136.15			
		$365.60		
Freight to Westfield		787.07		
d. Labor unloading plant	$363.87			
Teaming to work	419.14			
Storage and rent of siding.	91.09			
		874.10		
Total cost to plant job			2 026.77	1.03
Carried forward			$13 951.45	7.43

			Per Cent. of Contract.
Brought forward		$13 951.45	7.43
e. Removing general plant, labor	$481.92		
Transportation of same	631.29		
Total to remove plant		1 113.21	0.6
f. General plant repairs, labor	$617.12		
Materials for same	365.23		
Total general plant repairs		982.35	0.52
g. General plant depreciation		1 958.56	1.0
h. Building office, labor	$417.14		
Materials for same	415.04		
Furnishings for office	225.04		
Total for office		1 057.22	0.56
i. Maintaining office building.			
Labor	$329.42		
Food and table supplies	2 171.65		
Kitchen and table utensils	136.18		
Total for maintaining		2 637.25	1.4
j. Amount paid for small tools and supplies	$1 536.71		
Care of tools	59.40		
Total for small tools and supplies		1 596.11	0.84
k. Blacksmithing.			
General labor	$961.01		
Supplies	87.16		
Total for general blacksmithing		1 048.17	0.55
Grand total for General Expense		$24 344.32	12.9

Comment on the above figures: The percentages given indicate the per cent. to be added to all other costs to cover the cost of this particular item. It will be noticed that in the aggregate the charge of 12.9 per cent. must be added to the direct cost of each contract item to cover its proportion of General Expense.

In explanation of the several items entering into the General Expense account, the following comments may be made:

Item *a* refers to the general labor and teams involved of a miscellaneous character. It also covers the cost of incidental small supplies furnished from time to time for the general mainte-

nance of the work. Items *c* and *d* relate to the original shipping and delivery of tools, plant and apparatus preparatory to commencing work, while Item *e* refers to the final removal of same. Item *f* covers the expense of repairs on such plant as was used for general purposes. Item *g*, the depreciation on this plant. Item *h* refers to the building and furnishing of an office building which contained in addition living quarters for the superintendent, foremen, timekeeper, etc. This building was of rough construction, 30 ft. by 30 ft. in plan, with an upper story 30 ft. by 20 ft. The lower story contained a public and private office, a large dining room, a kitchen and a cook's living quarters. The second story contained eight sleeping rooms, each 8 ft. by 6 ft. The outer walls were protected by tar paper and the roof by "Rubberoid" roofing. It is possible that a smaller building would have answered the purpose equally well with a material saving in first cost. Item *i* refers to the expense of maintaining the office building, including the cost of board for the superintendent, foremen, timekeeper, etc., who were fed and quartered by the company in addition to receiving their usual salary. It may be of interest to add that the average cost per meal served, including all expense for kitchen and table ware, together with the services of the cook, amounted to 25 cents. Item *j* covers the cost of purchasing and caring for all small tools. Item *k* takes care of the balance of the expense of the blacksmith shop which could not be otherwise divided and charged direct.

Transportation.

The location selected for these works lies in that part of Westfield known as Mundale, at a distance from the railroad siding of approximately $5\frac{1}{2}$ miles and at an altitude approximately 300 ft. higher than that of the town proper. It was reached for the most part by means of a rough country road containing many sharp grades, some of them as great as 15 per cent. The road was exceedingly dusty in dry weather and exceptionally muddy in wet weather, making the transportation problem difficult and expensive. A pair of horses would make two trips daily from the railroad siding, hauling 3 000 lb. to the load, and in bad weather two teams traveled together, doubling up on the steep grades.

A steam traction engine was tried as an experiment, but this method of hauling was abandoned after one trip, the failure being due partly to the poor condition of the machine itself and

largely to the poor condition of the road and the steep grades which caused the water level to vary in the boiler, flooding the steam dome when going up hills and uncovering the crown sheet when going down. An experiment was then made with a gasoline-driven traction engine, and this, too, resulted in failure owing to the existence of several sandy sections of road which destroyed the tractive force of the wheels and made it difficult for the engine to propel itself even without its load. Later on, an automobile truck was introduced and proved to be a marked success. The truck was of two tons' capacity, made by the Reliance Company, of Detroit; and by using a longer but better road succeeded in making six trips per day, carrying two tons per trip. It is highly probable that had two of these trucks been purchased in the beginning of the work, a great saving would have been effected in the cost of hauling materials. Although successful as a means of transportation during the summer months, the automobile truck was obliged to give up the work when the late fall arrived, because of the frost in the ground, which thawed out sufficiently at midday to make the roads muddy on top with ice underneath. This condition rendered the operation of the truck on the steep grades very dangerous, and it was deemed best to withdraw it from service. The great bulk of the transportation was, therefore, handled with horses, and was let out by the ton to various teaming contractors, the prices varying from $1.50 to $2.00 per ton, according to the nature of the materials to be hauled. The total tonnage of all kinds hauled from the railroad to the work was approximately 5 000 tons and cost $1.65 per ton, or an average of 30 cents per ton mile. The following table shows the character and relative amounts of the materials hauled.

	Lb.
Plant, etc.	1 098 846
Cement	6 114 200
Akron pipe	522 239
Cast-iron pipe	635 200
Coal	1 298 100
Lead	8 800
Steel reinforcement	51 870
42-in. steel pipe	100 000
Castings, etc.	30 820
Hay	24 875
Grain	412 000
Miscellaneous	74 496
Total	10 371 446

Clearing and Grubbing.

The work required to be done under this classification included the removal of stumps, roots, brush and rubbish from about 10.44 acres, comprising the area covered by the sedimentation basin and the earth dam. This site had originally contained a rather thick growth of timber, the average size of which may have been 12 in. in diameter, but nearly all of this timber had been cleared prior to the letting of the contract, so that the removal of stumps and roots only was necessary. Fig. 7 shows the site before, and Fig. 8 after, grubbing.

The removal of the stumps, consisting largely of red oaks, chestnut and maple, was exceedingly difficult. The land was very rocky, with frequent outcroppings of ledge, and a large percentage of the stump roots either grew out of fissures in the ledge or extended underneath large bowlders. A stump-pulling machine of the Hawk-Eye type was used, consisting of a vertical windlass operated by a lever and a horse traveling in a circle. A considerable number of stumps was removed by blasting, and many of them too large for the puller to handle were split with dynamite and pulled piecemeal. A record of the number of stumps removed was kept and showed an average of 475 per acre. Owing to the fact that the basin was designed for use as a sedimentation basin, and that its bottom would consequently be covered by an increasing depth of silt and vegetable deposit, complete grubbing was not required. The bottom was entirely cleared of stumps, large roots and all loose material and was then burned over. The detail cost per acre for this grubbing is shown in the following table.

Cost per Acre for Grubbing.

10.44 acres, 4 964 stumps pulled.

Cost of labor pulling stumps.........	$83.76 per acre	
Cost of teams pulling stumps........	28.15	
Cost of explosives..................	9.06	
Total cost for stump pulling		$120.97 per acre
Cost of labor burning stumps........	$37.64 per acre	
Cost of stump puller and special tools.	17.32	
Total..................................		$54.96 per acre
Carried forward....................		$175.93

Average cost per stump pulled, 37 cts.

Brought forward		$175.93
Cost of labor grubbing roots	$56.16 per acre	
Cost of teams grubbing roots	2.09	
Cost of special tools and supplies	1.97	
Total cost of grubbing		$60.22 per acre
General expense, 12.9 per cent		$30.46
Total cost for this item per acre		$266.61

Comment on above figures: The cost as shown above is undoubtedly high for this class of work and may be accounted for partly by the fact that no special study was made of the possibilities of economic handling. This work was in general used as a spare job whenever there were extra men available. On the other hand, there is little question that the cost of grubbing work is too often underestimated and underbid and that the actual costs are in many cases much higher than popular impression would indicate. The general character of this work was probably more difficult than the average case, the rocky soil and the nature of the growth rendering it very difficult. Had it been necessary, however, to completely remove all fine roots, the above figures would have been largely increased.

The contract price for this item was, per acre	$150
The maximum price bid was, per acre	300
The minumum price bid was, per acre	100
The average price bid was, per acre	194

General Excavation.

The item of General Excavation included all excavation for the filters, for the aërator and various building foundations, for stripping at the site of the dike, and in general all cases of earth excavation required under the contract in which the depth of the excavation was less than its breadth. The total amount of yardage included under this item was 56 147 cu. yd., of which 45 081 cu. yd. were handled by steam shovel and 11 066 by hand loading.

The excavation for the filters was handled for the most part by a steam shovel, while all other General Excavation, including a small amount in the filters, was excavated and loaded by hand labor. The cost records were so kept as to only designate between these two methods. Some further division might have been made with advantage, as there was, of course, a material difference in the conditions surrounding the different

FIG. 7. VIEW OF SEDIMENTATION BASIN BEFORE GRUBBING.

FIG. 8. VIEW OF SEDIMENTATION BASIN AFTER GRUBBING.

Fig. 9. Site of Filters at Commencement of Work.

Fig. 10. Steam Shovel used in Excavating for Filters and Character of Material Encountered.

classes of hand excavation. Unfortunately, however, this was not done and the cost results shown for hand excavation represent an average cost for the several cases.

Steam Shovel Excavation.

The site on which the filters were constructed was originally part of an open clearing adjacent to the highway and had been under cultivation more or less. (See Fig. 9.) A brook of substantial size passed longitudinally through the lot but was diverted under the contract to a new and permanent location so that it offered no serious problem. The contour of the ground was such that a fill of a few feet was required for a small area at the easterly end in preparing the subgrade of the filter floor at that point, while at the westerly end a 17-ft. cut was necessary for the same purpose, the original surface grade being approximately uniform between these points. This condition necessarily involved a considerable amount of light cutting in the easterly half of the filter lot.

Previous to the letting of the contract, test pits had been sunk to grade by the city authorities at three points on a line running longitudinally of the site, for the purpose of determining the character of the proposed excavation and for the assistance of intending bidders. All of these pits showed a very fair quality of gravel somewhat cemented by nature, but with no indication of the existence of bowlders or ledge. It was assumed, therefore, that the material shown by these pits was fairly indicative of the nature of the material to be encountered throughout. This assumption was erroneous, as will be subsequently shown.

On account of the large amount of light cutting on the first half of this excavation and the consequent frequent moving which would be required, it was decided to install a No. 1 Thew steam shovel of the traction type, equipped with a $1\frac{1}{4}$-yd. dipper. This make of shovel possesses a great advantage over the ordinary type of steam shovel in light cutting work, owing to the extent of horizontal motion imparted to the dipper during the loading process. With this machine it was possible to crowd the dipper 7 ft. horizontally along the ground at each scoop. It can be readily understood that in cuts of from 1 to 2 ft. a reasonably full dipper load can be picked up in this manner. The Thew shovel of this size is made to revolve on the truck in a manner similar to that of a locomotive crane, so that it may dig or dump at any point within the circle of its swing. It weighed when in use about 30 tons, was mounted on wide flanged traction

wheels and was self-propelling. The machine used on this work was delivered by freight at Westfield, was unloaded and assembled there and brought to the work over 6½ miles of highway on its own wheels and by its own power. It required six days to accomplish the task, being equivalent, therefore, to an average of a little better than one mile per day of travel. Owing to its weight and the poor quality of the roads passed over, it was necessary to lay a plank track for nearly the entire distance to prevent the wheels from sinking through the road bed. The cost of unloading from the car, assembling and transporting this shovel to the work was $255.15. It required for operation an engineer, a fireman and two laborers who trimmed up the bottom of the pit and assisted in moving.

Satisfactory progress was made in excavating for the first two filters. The nature of the material encountered up to this point was, if anything, somewhat better than that shown by the test pits. An output of from 300 to 500 cu. yd. per day was maintained during this period.

Except when moving, which, of course, occurred often in this shallow cutting, no difficulty was found in loading a team per minute, and as the dumping point was then at the base of the dike, the haul was over practically level ground.

When excavation for the third filter was reached, many large bowlders were encountered, and from that point onward their occurrence became general. An idea of their prevalence may be had from the view shown in Fig. 10. The work of excavation now became most tedious and expensive. The shovel, although not designed for such work, was able to dislodge many of the small bowlders of 1 cu. yd. or less, but a large percentage were of such size as to require blasting before the shovel could proceed. The delays incident to meeting these obstructions frequently reduced the daily average to less than 100 cu. yd. In some places bowlders were so thickly grouped in the ground that it was necessary to resort to hand excavation to clear around and remove them. The gravel surrounding the bowlders was cemented to such an extent as to almost resemble concrete. Attempts were made to blast the bank ahead of the shovel, but it was impossible to drill into the material with any degree of success. The ground contained so large a percentage of stone, both large and small, that neither a churn drill nor a steam drill could be put down without its course being deflected. There remained nothing to do but to scratch away the gravel from around the bowlders and pry them out with the dipper or other-

wise to blast them. Added to the frequent delays from bowlders, breakdowns of the shovel due to the excessive strain upon it occurred almost daily. This, of course, was to be naturally expected when using a 30-ton shovel on work requiring a 60- or 70-ton machine.

Although the excavation for the filters was nearly completed during the first season, the delay caused by the unexpected nature of the material prevented the completion of both the filter excavation and masonry in that season.

As practically all of the excavated material was to be utilized in fills, either in the earth dam or in grading over and around the completed filters, no satisfactory system of car transportation for the excavated material was deemed available. Two-horse teams hauling bottom-dump wagons were used throughout the work, and the excavated material was deposited without further rehandling in its final position. The elevation of filter subgrade was 455, while that of the finished dam was 495, necessitating a final maximum up-hill haul of 40 ft., although the haul was practically level to the base of the dam. Various schemes for using incline railways and cable machines in transporting the excavated material were considered but finally abandoned as impracticable, and dependence placed entirely upon horses. When the fill on the dam had progressed to about elevation 475, or 15 ft. above the normal surface level at its base, it became necessary to devise some means of assisting the teams up the steep grade to the surface of the fill. This was accomplished in the following manner.

A short, steep road was selected up the side hill at the westerly end of the dam and an 18-in. gage railway track laid in a straight line from the bottom to the top of this road. A hoisting engine was installed at the top of this track and a weighted car, consisting of a small steel tank filled with concrete and mounted on four wheels, was operated up and down the track by this engine with a cable. The top of this car was just high enough to catch the rear axle of the wagons. In operation the teams drove on to and over the track near its lower end and headed uphill with the wheels astride the track, the car at this time being at the lower extremity of the railway. The car was then started up the track, catching against the rear axle of the wagon, and practically boosted the load uphill, the horses being only required to keep the pole headed in the proper direction. At the top of the track the team swung off downhill toward the fill, and the car ran back by gravity to await the next load.

The grade of this road was about 18 per cent. and its length about 150 ft. The teams could be handled on it at the rate of one per minute. This device is shown in operation in Figs. 11 and 12.

The detailed cost of steam shovel excavation, including that of teaming it to its disposal point was as follows:

Cost of Steam Shovel Excavation in Filters.

45 081 cu. yd.

Cost of delivering and installing shovel ready for work		$0.011 per cu. yd.
Cost for foreman supervising excavation		0.037 per cu. yd.
Cost of shovel operation, labor	$0.047	
Cost of coal, oil, etc.	0.033	0.08 per cu. yd.
Cost of repairs, labor	$0.007	
Cost of repairs, materials	0.014	0.021 per cu. yd.
Cost of depreciation on shovel		0.039 per cu. yd.
Cost of teaming excavated material		0.215 per cu. yd.
General expense, 12.9 per cent		0.052 per cu. yd.
Grand total cost, including all expenses		$0.455 per cu. yd.

Comment on above figures: The cost of installing shovel includes the expense of four sections of oak platform, each section being 12 ft. long by 5 ft. wide and 4 in. thick. Each section was fitted with lifting rings so that it could be easily handled by the dipper of the shovel and transferred from the rear to front as the shovel was moved forward. A second set was required after a few months' use. This second set of platforms was made from rock maple and remained in use through the balance of the work. The cost of the subsequent removal of the shovel is not included in the above figures but is charged to another item of work on which the shovel was later used.

The charge for foreman is an average charge per cubic yard for all foremen and subforemen employed on General Excavation during the work.

The cost of shovel operation includes, in addition to the engineer and fireman, all laborers required in the pit.

The cost of repairs is exceptionally high on account of the very difficult nature of the work performed. Two new booms were supplied by the makers to take the place of broken ones, the second being of a special design. Several new dipper arms were required, and the dipper teeth, chains and ropes were

FIG. 11. DEVICE FOR ASSISTING TEAMS UP HILL TO EARTH DAM.

FIG. 12. TEAM BEING ASSISTED UP HILL.

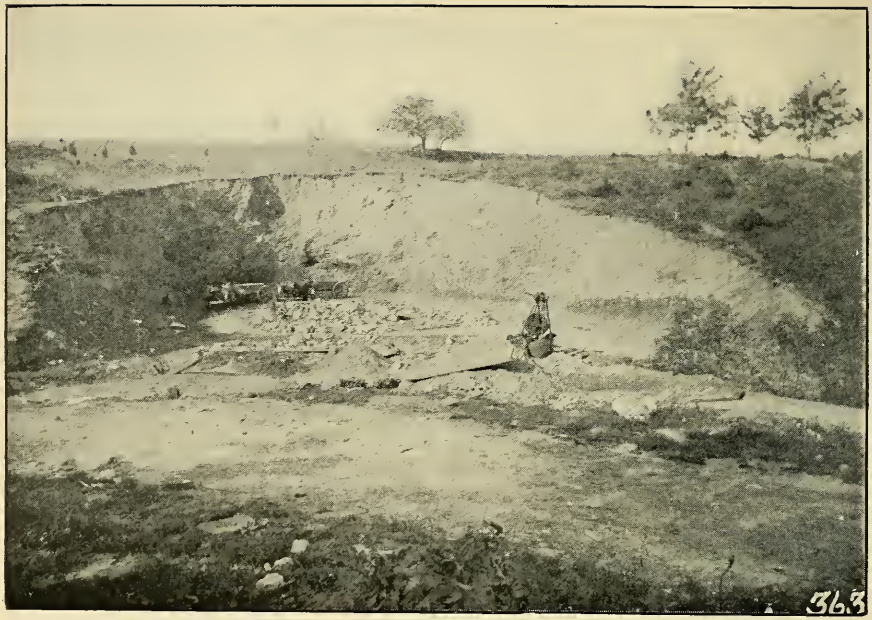


FIG. 13. VIEW OF BORROW PIT FOR CLAYEY MATERIAL.

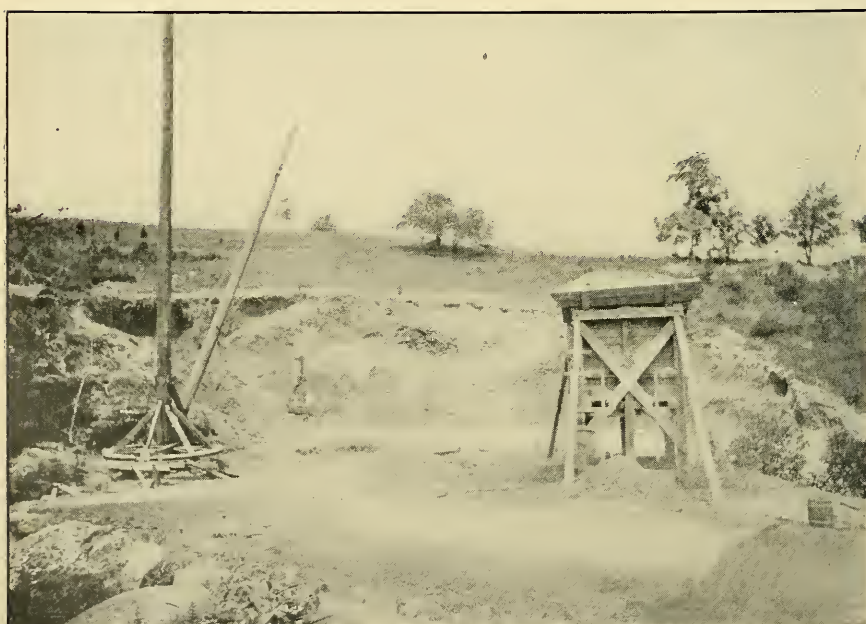


FIG. 14. VIEW OF LOADING APPARATUS AT BORROW PIT.

replaced every few weeks. The thought may suggest itself that it would have been economy to have installed a larger shovel when the difficult excavation was encountered. It was, however, expected from day to day that the character of the excavation must change for the better, since the original test pits showed no rough material and the earlier material encountered had been easily handled. The depreciation charged may possibly appear large, but is in reality the actual shrinkage in value between its new and its selling price. The entire depreciation is charged to this item although the shovel was used on two subsequent items. This is due to the rougher usage suffered by it comparatively on this part of the work and is undoubtedly somewhat unfair to this item.

The teaming was done as before stated, with bottom-dump wagons hauling ordinarily one dipperful from the $1\frac{1}{4}$-yd. dipper. During the early stages of the work, when the hauling was over approximately level roads, two small dipperfuls were carried. The greater part of the excavated material was deposited in the earth dam at an average haul of about 800 ft. each way and, as previously explained, over an uphill road. A small amount was used in filling over and around the filters at an average haul of approximately 500 ft. each way, but the bulk of this fill was obtained from another source. No dumping expense is charged to this item as all labor of that nature is chargeable to the items of Earth Embankment or to General Fill.

The number of actual working days required to complete the filter excavation was 191, representing, therefore, an average of only 236 cu. yd. per day.

Hand Excavation.

As previously stated, 11 066 cu. yd. of General Excavation was loaded by hand methods. A small amount of loam stripping over the filter site was done with wheel scrapers. Much of the area to be stripped, however, was of a marshy nature, due to the presence of springs at the upper end of the lot. This rendered the soil so soft as to prohibit the working of horses over it. Other parts of the lot were so stony under the surface as to continually stall the scrapers, and the scraper method of excavation was finally abandoned and wagons and shovels substituted therefor. Reference has already been made to the use of hand-loading in certain parts of the filter excavation, i. e., in spots where the bowlders were so numerous as to actually block the shovel. This class of excavation was, of course, naturally very

expensive, requiring the picking of cemented gravel from under and around the bowlders.

The permanent diversion of the brook required about 1 200 cu. yd. of excavation, which was executed entirely by hand methods. Part of this channel was quite deep and required some staging and rehandling for the bottom part.

Excavation for the office and laboratory building, for the regular house and for the aërator were carried to depths of 7, 9 and 7 ft. respectively. The material in this excavation was cemented sand and gravel, requiring loosening with picks but without the presence of bowlders.

The removal of all soil covering the area of the dam site and the first four feet in depth of the cut-off wall trench were also handled by hand. Excavation for central drains in each filter was also done by hand labor and was exceedingly difficult, being composed mostly of small bowlders. The following figures give the average cost of all work above enumerated.

Cost of General Excavation removed by Hand Labor.

11 066 cu. yd.

Foreman	$0.037 per cu. yd.	
Picking and shoveling	0.527 per cu. yd.	
Miscellaneous supplies	0.005 per cu. yd.	
Teaming	0.215 per cu. yd.	
Total		$0.784 per cu. yd.
General expense, 12.9 per cent		0.101
Grand total cost of this item		$0.885 per cu. yd.

Comment on above figures: The charge of $0.527 per cu. yd. for picking and shoveling is probably high in spite of the difficulties experienced in some portions of the work. There is a tendency to use such jobs as these for spare work on which to employ a few men from time to time when they are temporarily prevented for some reason from following their usual duties, and for this reason efficiency is not always looked for or attained. On the other hand, excavation in and around bowlders may easily cost one dollar or more per cubic yard, and partly accounts for this high average. The average cost of all general excavation, including both steam shovel and hand loading, was 54 cents.

The contract price for this item was	$0.35
The maximum price bid was	0.60
The minimum price bid was	0.35
The average price bid was	0.46

It should be borne in mind that these prices were bid upon the expectation of encountering an entirely different class of material from that actually met with, viz., the moderately cemented sand and gravel free from bowlders as indicated by the test pits.

Trench Excavation.

Various pipes and drains in connection with the several parts of the work required 4 759 cu. yd. of trench excavation. Of this amount, 653 cu. yd. were in the cut-off trench for the earth dam.

In general, all excavations whose depth exceeded their width were classed as trench excavation. The excavation in the cut-off trench of the dam involved special treatment and was subsequently handled and paid for as a separate proposition.

The average cut of the many pipe trenches was about 7 ft. and their average width at the bottom was approximately $4\frac{1}{2}$ ft. The specifications provided that the measurement for payment should include slopes of 2 vertical to 1 horizontal, regardless of whether more or less was actually removed. The general nature of the material, however, was such as to allow vertical banks in all cases, being a compact cemented sand and gravel mostly without bowlders. The cost of this work was as follows:

Cost per Cubic Yard of Trench Excavation.

4 106 cu. yd.

Picking and shoveling, including backfilling,	$0.243 per cu. yd.
General expense, 12.9 per cent...........	0.032 per cu. yd.
Grand total for this item..............	$0.275 per cu. yd.

Comment on above figures: This figure is small because of the excess measurement allowed under the contract for the slopes which were not excavated. The actual excavation was only about 60 per cent. of the measurement allowed in accordance with the specifications. The unit cost for the amount actually removed would be approximately 46 cents. This excavation required no removing of surplus as in all cases it was possible to distribute it over the surrounding ground.

The contract price for this item was........	$0.75
The maximum price bid was...............	1.50
The minimum price bid was...............	0.45
The average price bid was.................	0.922

Borrowed Excavation.

This item of the work embraced the securing and delivery of such material as was required for the fills in excess of that supplied from General Excavation. It was originally expected that Borrowed Excavation would only be necessary in supplying about 16 500 cu. yd. of clayey material for the core or middle portion of the earth dam. It subsequently became necessary to increase the amount of borrow to 30 000 cu. yd. on account of the deficiency of material caused by the elimination of bowlders and large stones from the material brought from General Excavation.

Material conforming to the requirements of the specifications for use in the core of the dam was obtained on land belonging to the city, at a distance of approximately 2 500 ft. from the dam in an uphill direction. The haul from this point to the dam was, therefore, downhill to the filter site, from which it was necessary to haul up grade as the dam fill increased.

The material was a compact, clayey sand, containing at times a moderate amount of gravel. Its location in a side hill afforded an excellent opportunity for loading and eventually a face of 50 ft. in height was obtained. (See Fig. 13.)

An attempt was made to loosen the material by blasting, using black powder in holes drilled some distance back from the face. It was found, however, that water seeping through the material wet the holes, and even when not troubled from water the shots were unsatisfactory, due mainly to the elastic nature of the material.

An attempt was then made to loosen a large section of the bank by means of a tunnel driven into the hill and exploding a mine therein. Again the result was unsatisfactory, the effect of the shot manifesting itself in the shape of a small crater while only a comparatively small amount of material was loosened in proportion to the amount of labor and explosives required. A successful method of loosening was finally obtained by the use of undercutting shots. A row of short holes were churned in diagonally downward along the base of the vertical face of the pit. These holes were fired simultaneously, using dynamite for the purpose. The resulting shot kicked out a triangular strip of the material from under the face, while the shock of the explosion caused the overhanging mass above to crack and topple over, thereby breaking it into a loose pile which was easily shoveled. At times, after the face had reached a considerable height, four

or five holes loaded with ten or fifteen sticks of dynamite would loosen and break up from 100 to 150 cu. yd.

For loading the material into wagons a large guyed derrick was installed and equipped with a one-yard orange-peel bucket which delivered into a hopper under which the teams drove and received their loads. (See Fig. 14.) This arrangement was very satisfactory while working, but the frequent delays caused by minor breakdowns and repairs rendered it uneconomical. Material from this pit was required sometimes at the rate of a load every three minutes, and it can be readily understood that a delay of a half hour while repairing a broken chain or worn-out sheave might result in the tying up for that time of ten teams and in the disorganization of the work on the dam where this filling was needed in an amount proportionate to that of the other material being placed. It was finally deemed more satisfactory and dependable to load this material by hand, and after the second month of the work hand-loading was used entirely. It was estimated at the time that, considering the expense, direct and indirect, due to delays, it would be more economical to use old-fashioned methods.

As stated above, the average length of haul from the pit was about 2 500 ft., or a round trip of 5 000 ft. The greatest number of trips per team, made or required, was 20 in 10 hours. The average for the entire work was about 18. The wagons holding $1\frac{1}{2}$ cu. yd. level measure were ordinarily well rounded up when leaving the pit, but the average load, bank measure, was only about 1 cu. yd.

The nature of the material rendered it difficult to team over during or immediately after wet weather, and the same was true of the highway over which the teams were obliged to pass. On the other hand, in dry weather the highway was deep with dust, adding another unpleasant feature.

The cost of this item of the work was as follows:

Cost of Excavating and Teaming to Dam of Clay Borrow for Core Wall.

13 952 cu. yd.

Blasting.		
Cost of labor drilling holes......	$0.017 per cu. yd.	
Cost of explosives.............	0.018 per cu. yd.	
Total cost of blasting.................		$0.035 per cu. yd.

Brought forward		$0.035
Loading.		
Cost of foreman, laborers, etc.	$0.2022	
Cost of coal, oil, plant, etc.	0.0226	
Cost of special tools used	0.0014	
Total cost of loading		$0.226 per cu. yd.
Cost of teaming to dam		0.36 per cu. yd.
General expense, 12.9 per cent		0.08 per cu. yd.
Grand total cost for this item		$0.701 per cu. yd.

Comment on above figures: The average cost of blasting would have been lessened had it not been for the expensive experimenting resorted to in the beginning. The labor item of $0.2022 for loading contains a charge of $0.045 for foreman, which may appear high, as a $5.00-a-day foreman was employed to supervise the work of 10 to 12 men. An attempt to substitute a cheaper foreman, however, resulted in increased cost and decreased output, and the more expensive man was returned. The cost of labor exclusive of foreman was $0.157, and represented an average of only a little over 11 cu. yd. per man. Much of the labor, however, was employed in maintaining roads, stripping loam, breaking and removing bowlders, etc., and it is probable that of the men actually employed in loading, an average of 15 yd. loaded per man was secured. This, of course, was not a large output for material which had already been loosened, but as an average of good and bad days extending over a long period is possibly all that could be expected.

The coal and oil were used on the mechanical handling apparatus during the short period of its use and the plant charges cover the cost of erecting and removal of same.

Since double teams cost $6.00 per day, the teaming charge of $0.36 gives an average of 17 cu. yd. per team per day. It may be added that but few teams could stand this work continuously, and frequent changes of teams were required to rest the horses.

The contract price for this item was	$0.70
The maximum price bid was	1.00
The minimum price bid was	0.50
The average price bid was	0.715

Second Borrow Pit.

When the filter excavation was completed it was found that additional material to the extent of several thousand yards would be required to complete the fills. This deficiency was due

to two causes, first, the shrinkage in volume due to the removal of stones, and, second, the excessive shrinkage due to compacting in fills especially under the roller.

A borrow pit was accordingly designated by the engineer located near the tunnel portal at the westerly end of the work, an average distance of 1 400 ft. from the dam and of 1 000 ft. from the general fill over and around the filters. The general level of the floor of this pit was somwehat higher than that of the finished dam, and at a slight expense a sidehill road was constructed, which permitted a practically level haul to this point. The steam shovel from the filter excavation was installed in this pit and worked under much more favorable conditions than it had met in the filter excavation. The material first encountered was of a compact, rough gravel, but this soon changed to a sandy clay which was used throughout the upper portion of the dam, both for core and outer fill.

The cost of excavation in this pit and teaming to the fills was as follows:

COST OF GRAVEL AND CLAY BORROW FROM SECOND BORROW PIT.
16 296 cu. yd.

Foreman		$0.022 per cu. yd.
Loading teams	$0.084	
Coal and oil	0.016	
Total cost of loading		0.10 per cu. yd.
Cost of moving shovel from filters	$0.004	
Repairs on shovel	0.082	
Total		0.086 per cu. yd.
Cost of teaming to fills		0.21 per cu. yd.
Constructing roads and bridges		0.012 per cu. yd.
General expense, 12.9 per cent		0.055 per cu. yd.
Grand total cost for this item		$0.485 per cu. yd.

Comment on above figures: The cost of loading is somewhat misleading, since it includes the loading by hand of all soil stripping, a total of 2 330 loads out of 13 843 loads taken from the pit.

It cost $55.50 to take the shovel out of the filter pit and install it ready for work in this borrow pit.

The cost of repairs is high, due to the replacing of several expensive parts which were worn out in the filter excavation. The charge against the present item, however, is perhaps fair, since no depreciation is included, it all being charged against General Excavation. The price of $0.21 for teaming corresponded

to a daily average per team of about 30 cu. yd. It will be noticed that the loads from this pit averaged 1.18 yd. bank measurement, the larger loads being due to the comparatively level haul obtained. The contract price of $0.70 per yard also applied to this work.

Rolled Embankment.

With the exception of a few hundred yards of fill in and around the northeasterly corner of the filters, this item related solely to the construction of the earth dam. This dam is shown in profile and section by Fig. 15. It was 740 ft. long at the crest and its maximum height above the natural ground was 35 ft. Its maximum width at ground level was 165 ft. The slopes were carried 1 on 2 and a roadway 16 ft. wide surmounted its top. A cut-off trench was carried to rock for the entire length, in which was built a concrete cut-off wall 3 ft. thick, extending upward from the ledge to a little above the natural surface. Surrounding this cut-off wall and extending upward through the middle portion of the cross-section is a clay core built with the material secured from the borrow pit previously described.

After the area to be covered by the dam had been grubbed and stripped of soil, and after the cut-off wall was constructed, material from the borrow pit was dumped, spread by hand and tamped on both sides of the wall until its level reached that of the surrounding ground. From the ground level the fill was carried upward as indicated on the cross-section Fig. 15, material from the filter excavation being dumped and spread on the two outside thirds and that of the clay borrow pit on the middle third. The several layers were so deposited that the clay and gravel lapped each other alternately at their joints, giving a dovetailed bond between the core and the main fill. The specifications required that the layers should be carried 4 in. in thickness. This provision, however, was not rigidly insisted upon, the usual thickness being at least 6 in., and at times even heavier layers were permitted if in the judgment of the engineer the material was of a nature to admit of proper consolidation by rolling. This feature is a most important factor in reducing cost, and must, therefore, be considered in connection with the cost figures herein given.

For a while the spreading was accomplished by means of a No. 2 Climax road machine drawn by two horses. The teams dumped the material in rows and the machine following leveled the rows to the required thickness. When the rough material

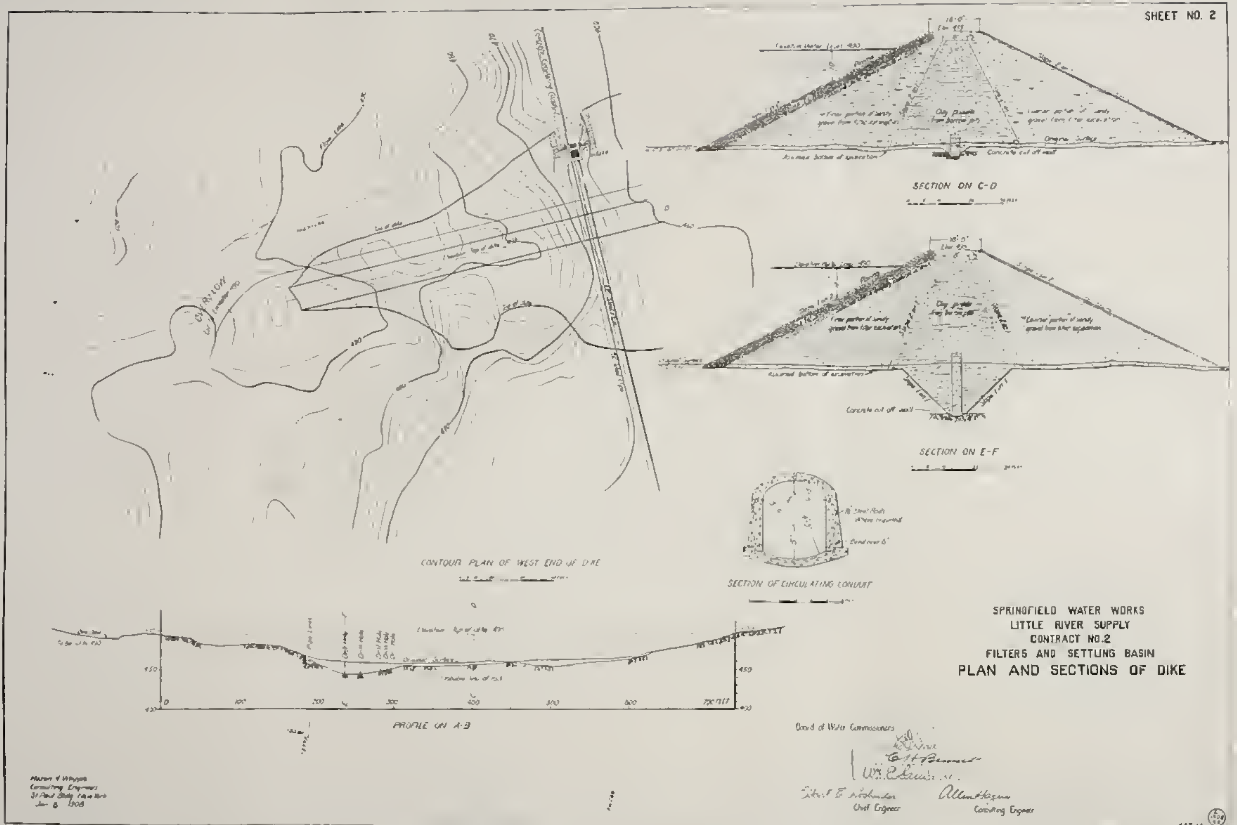


Fig. 15. Details of Earth Dam Construction.

was encountered in the filter excavation, it became impracticable to use the grader, as the large stones were so numerous that the machine was unable to spread the piles even when drawn by four horses. This necessitated recourse to hand-leveling and the use of a stone drag and teams to remove stones larger than 6 in. in diameter which the specifications directed should be excluded from the fill. Small stones from 6 in. to 12 in. in size were thrown down the slopes, those on the upstream side remaining there and constituting part of the 3-ft. rock fill called for on that slope, while stones thrown out on the downstream slope were collected and teamed to the crusher to be broken for use in concrete. All large stones were loaded on a drag and rolled into the rock fill.

The specifications provided for the rolling of the embankment with a grooved roller weighing not less than $1\frac{1}{2}$ tons per linear foot of roll. This provision, of course, necessitated the use of a power roller. For a short time a traction engine weighing about 10 tons was used for the purpose and gave excellent results so far as the quality of rolling was concerned. It was out of commission so often, however, due to breakdowns and defects, that a new Buffalo-Pitts tandem type of roller was purchased and its two rolls equipped with heavy steel bands to give them the grooved effect. This roller was rated by the makers at 8 tons, but with its boiler and tank filled and the added weight of the steel bands it actually weighed 12 tons. This total weight of the roller produced the necessary load specified by the specifications on each of its two rolls, consequently every layer received two rollings every time the roller passed, each conforming to the specified requirements.

While awaiting the arrival of this roller, a horse roller weighing $2\frac{1}{2}$ tons, or $\frac{1}{2}$ ton to the linear foot of roll, was used and was drawn by four horses. This roller did not, of course, meet the contract requirements, but a temporary concession was made in the matter by the engineer during this interval. This same horse roller was later used near the top of the dam during a short interval while the steam roller was undergoing repairs. It is estimated that from 8 000 to 10 000 cu. yd. of this embankment were rolled with the horse roller.

Considerable difficulty was encountered in rolling the clay core after a rain storm, with the heavy roller. This material when once wet retained the moisture for a long period and when saturated assumed a jelly-like consistency. On such occasions, layers of gravelly material were spread over it and rolled until

the clay squeezed up through it. Sometimes several layers of gravel were required to stiffen the clayey material sufficiently.

As a general thing, the teams passed over the dam longitudinally with their loads, and it is highly probable that the grooving action of the wheels together with the tamping action of the horses' hoofs was of great assistance in consolidating the fill.

Very little watering was required, as the material from the filter excavation was usually moist if not wet, and it was found difficult to wet the clay without softening it too much. Fig. 16 illustrates the general features of the dam construction and also shows the roller at work.

It is unfortunate that there is no way of determining accurately the amount of shrinkage suffered by the material due to rolling and otherwise compacting it. It is known that there were 86 400 cu. yd. of material excavated in general and in borrowed excavations, while only 75 700 cu. yd. were finally measured in fills. This shrinkage of 11 000 cu. yd. includes approximately 1 000 cu. yd. wasted, and in addition the volume of stones and bowlders rejected from the fills. It seems probable to the writer that 5 000 cu. yd. would conservatively cover these two sources of loss, leaving 6 000 cu. yd. due to shrinkage by compacting. This 6 000-yd. shrinkage undoubtedly occurred entirely in the rolled embankment, as the general fill was not compacted except by the teams driving over it. If this assumption is correct, it would indicate a shrinkage of 11 per cent. in volume due to rolling and compacting, and would be, therefore, an important factor not to be overlooked when estimating the amount of material required for similar fills.

In spite of the occasional deviation from specified requirements, both as to thickness of layers and of intensity of rolling, this dam when finally completed, and subjected to its full hydrostatic head of water did not show a single indication of leakage, and after a year's test under service conditions still remains absolutely water tight.

The cost of building this embankment was as follows:

Cost of Rolled Embankment.

	53 233 cu. yd.	
Cost of labor and teams used in spreading material and picking stones	$0.0435 per cu. yd.	
Cost of labor making roads and bridges	0.001 per cu. yd.	
Miscellaneous supplies	0.0005 per cu. yd.	
Total for spreading in layers		$0.045 per cu. yd.

Brought forward		$0.045
Cost of operating steam roller	$0.0098 per cu. yd.	
Cost of coal, oil, etc	0.0055 per cu. yd.	
Depreciation and repairs on roller	0.017 per cu. yd.	
Cost of teams on horse roller	0.0076 per cu. yd.	
Total cost of rolling		$0.0399 per cu. yd.
Cost of teams watering		0.0008 per cu. yd.
Cost of foreman		0.0151 per cu. yd.
General expense, 12.9 per cent		0.013 per cu. yd.
Grand total cost for this item		$0.1138 per cu. yd.

Comment on above figures: Owing to the use of bottom-dump wagons, the labor was much less than it would have been with end-dump carts or cars. The presence of so many large stones in the loads necessitated at least 50 per cent. more labor than would otherwise have been required.

The labor on roads and bridges was used in maintaining satisfactory approaches to and returns from the dam.

The gross cost of both steam and horse rolling has been divided into the entire yardage of the dam. The steam roller was used in rolling probably 85 per cent., while the horse roller was used on about 15 per cent. of the whole volume rolled. As a matter of fact, the daily cost of operating the steam roller was not much if any less, if depreciation and repairs are included, than that of the horse roller using four horses.

Depreciation was large in this instance since the roller was purchased new and disposed of at second-hand price at the completion of the work.

The item of watering is almost negligible but might easily become important in the case of a different material requiring more wetting.

The charge for foreman constituted a substantial fraction of the grand total, yet a competent and consequently high-priced man was necessary to intelligently supervise the placing and to direct the teams.

The contract price for this item was, per cu. yd	$0.16
The maximum price bid was, per cu. yd	0.48
The minimum price bid was, per cu. yd	0.10
The average price bid was, per cu. yd	0.242

General Fill.

The work embraced under this item included the fills around and over the filters, the grading and loaming of the same and all other fills around the grounds which might be made under the

direction of the engineer. It was originally expected that the first four filters built would be backfilled with earth teamed directly from the steam shovel, but that the material required to fill over the last two filters would be temporarily stored in spoil banks and be subsequently rehandled to the fill, since the last of the filter excavation would naturally be removed before the roof of the second last filter was completed ready to receive the fill. Owing, however, to the shortage of material available for fills, and the subsequent opening as previously described of a special borrow pit, this part of the fill was also deposited directly from its excavation point and without rehandling. This condition, therefore, effected a substantial saving in the cost of this work.

The loam originally stripped from the filter site was the only earth rehandled under this item, representing perhaps 1 000 yd. The balance of loam necessary to cover the various fills was paid for both as borrow and as general fill. With the exception of the 1 000 cu. yd. of loam mentioned, the expense charged to this item was limited to that of dumping, spreading and grading material hauled from the excavations.

The cost of general fill was as follows:

Cost of General Fill.

22 521 cu. yd.

Labor dumping, spreading and grading.........	$0.0618 per cu. yd.
Teams and labor rehandling 1 000 cu. yd. of loam,	0.0147 per cu. yd.
General expense, 12.9 per cent................	0.01 per cu. yd.
Grand total cost of this item..................	$0.087 per cu. yd.

Comment on above figures: The total expense of rehandling 1 000 yd. of loam is here divided into the entire yardage of the item. It actually cost about $0.33 per cu. yd. of loam rehandled, the average haul being about 500 ft. each way.

The contract price for this item was........	$0.22
The maximum price bid was...............	0.45
The minimum price bid was...............	0.17
The average price bid was.................	0.327

Concrete Masonry.

The proposal contained three separate items of concrete masonry, viz., "concrete masonry with reinforcement," "concrete masonry in piers and vaulting" and "all other concrete." The first class of concrete was mostly vaulting of slightly heavier design than the standard filter roof, reinforced to carry the

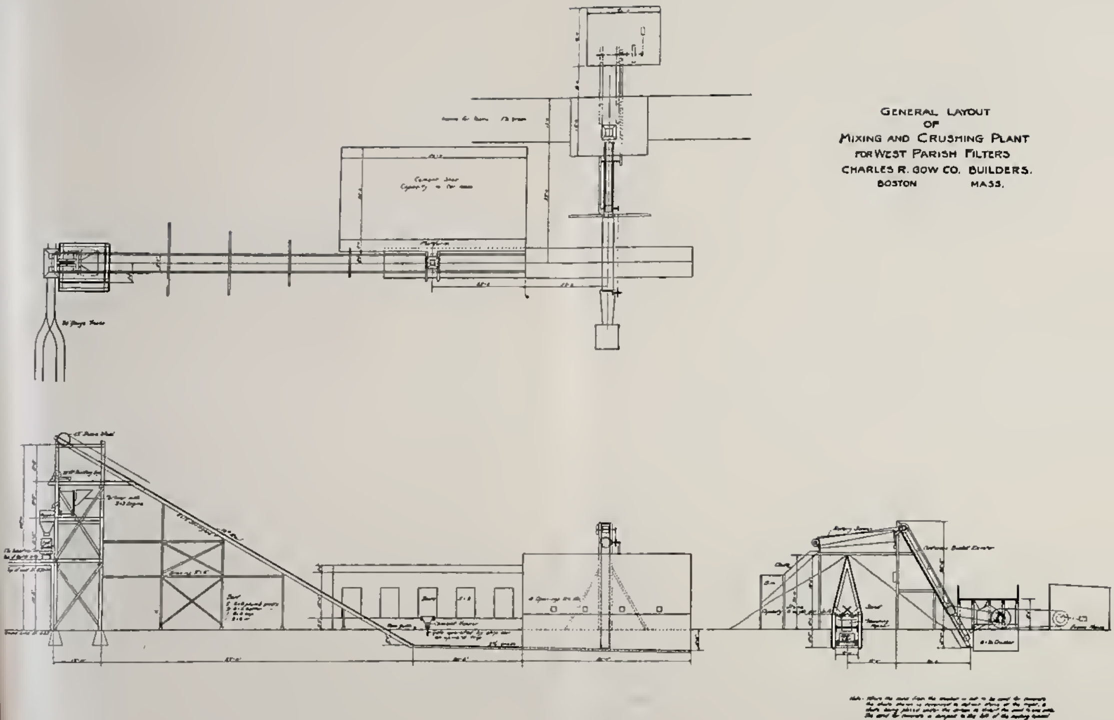
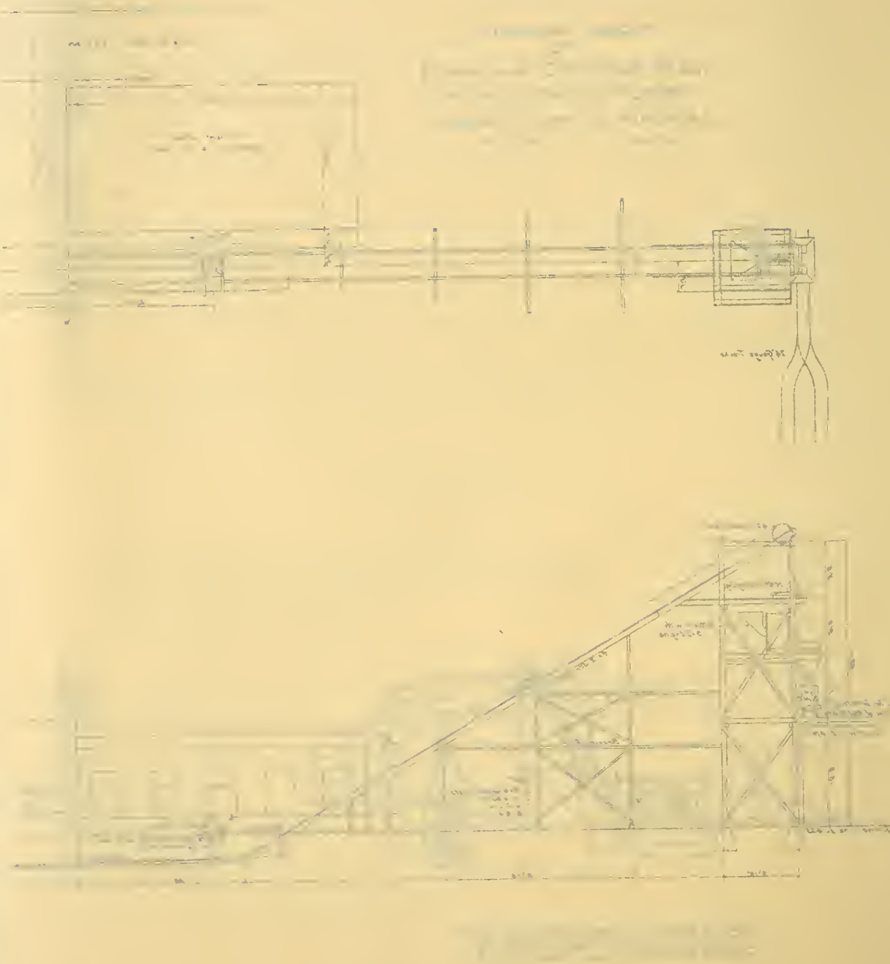

GENERAL LAYOUT
OF
MIXING AND CRUSHING PLANT
FOR WEST PARISH FILTERS
CHARLES R. GOW CO. BUILDERS.
BOSTON MASS.

FIG. 17.



additional load to be imposed by future sand storage. There was in addition a small amount of reinforced concrete conduit work, and the wall of the aërator contained some reinforcement.

"Pier and vaulting" concrete included concrete in all filter piers and roof exclusive of the small amount included in reinforced concrete. The contract price received was identical for "reinforced concrete" and "piers and vaulting concrete," and no special distinction was made between them in the cost records so far as the filter roof was concerned. "All other concrete" included the walls and floors of the filters, foundation and mass concrete and miscellaneous concrete masonry in various parts of the work.

Of the 13 282 cu. yd., total, of the several kinds of concrete placed, 81 per cent. went into the filters proper, 9 per cent. into the cut-off wall of the earth dam and the remaining 10 per cent. into miscellaneous structures such as conduits, buildings, aërator, etc. The concrete plant was consequently designed with the idea of convenient handling to the filters, leaving the other 19 per cent. to be transported by teams or otherwise as might be convenient.

In the attempt to design an efficient and economical handling plant for the purpose of the concrete work, a mistake was made which is not uncommon in many such cases, viz., the adoption of an elaborate arrangement, capable of a much larger output than could possibly be handled under the conditions existing and much more expensive than was justified by the quantity of concrete to be handled.

There was no ledge in the neighborhood, of a satisfactory quality, from which stone for crushing could be obtained. There were, however, many stone walls in the vicinity available for the purpose and also, as it proved, enough bowlders from the excavation to supply a sufficient quantity of stone for crushing. In addition, the sand pit located on city land about a mile above the work contained a considerable percentage of gravel and small cobble stones. It was deemed advisable to load this material as it ran in the bank and separate it at the crusher and screening plant, thus utilizing the stones and gravel which it contained and lessening to a considerable extent the quantity of stone to be secured and hauled to the crusher.

The plant as adopted is shown in Fig. 17. A 10-in. by 20-in. jaw crusher received the stone, which was hauled to the crusher platform in teams, where it was dumped and fed by hand. The teams from the sand pit were also dumped on an-

other part of this platform and their contents shoveled on to an inclined bar grating just above the opening of the crusher. This grating allowed the sand and gravel to fall through to the buckets of the 14-in. elevator which fed a 42-in. revolving screen. All large gravel and cobbles were rejected by the bar grating and fell into the crusher. The 42-in. revolving screen was located above and transversely across an A-frame partition, as shown on the plan, the sand and dust falling on the crusher side of the partition and the stones on the opposite side. The material thus separated piled against the opposite sides of the A-frame and by means of chutes and gates in its bottom walls were drawn into a measuring hopper which dumped into a skip car traveling on a track laid in a trench under the A-frame and below the level of the ground. The skip car was hoisted up a long incline, passing in its travel close by the cement shed and under a steel hopper into which the requisite amount of cement had been dumped. A suspended lever from this cement hopper engaged with the skip car as it passed, causing the cement to fall into the car with the other materials. The car continued on its way up the incline until it reached the proper elevation at the mixing tower, where it automatically dumped into the receiving hopper of a 1-yd. Ransome mixer. After emptying itself, the skip car returned by gravity to the loading trench, where the operation was repeated. The mixer was located in a high tower as shown on the plan and discharged the concrete into a delivery hopper which in turn fed into 1-yd. hoisting buckets traveling upon flat cars. These cars were conveyed by means of a service track and cable running longitudinally over the center line of the finished filter roof to within reach of the derricks used for placing.

The mixing tower was located on the extension of the longitudinal center line of the filter site at the easterly end of the work. As the excavation work commenced at this end, so also did the concrete work. As soon as a filter was completed, the service track from the mixing tower was extended over its completed roof. Views of the concrete plant as constructed are shown in Figs. 18 and 19.

The cost of the mechanical equipment embraced in this plant was about $5 000 at the factory. It cost in addition $600 to freight and transport to the work and $3 900 to install and maintain in working condition, making the total cost of the plant $9 500. It was easily capable of turning out a batch per minute or 600 cu. yd. per ten-hour day, but to have utilized this output

Fig. 16. View showing Earth Dam during Construction.

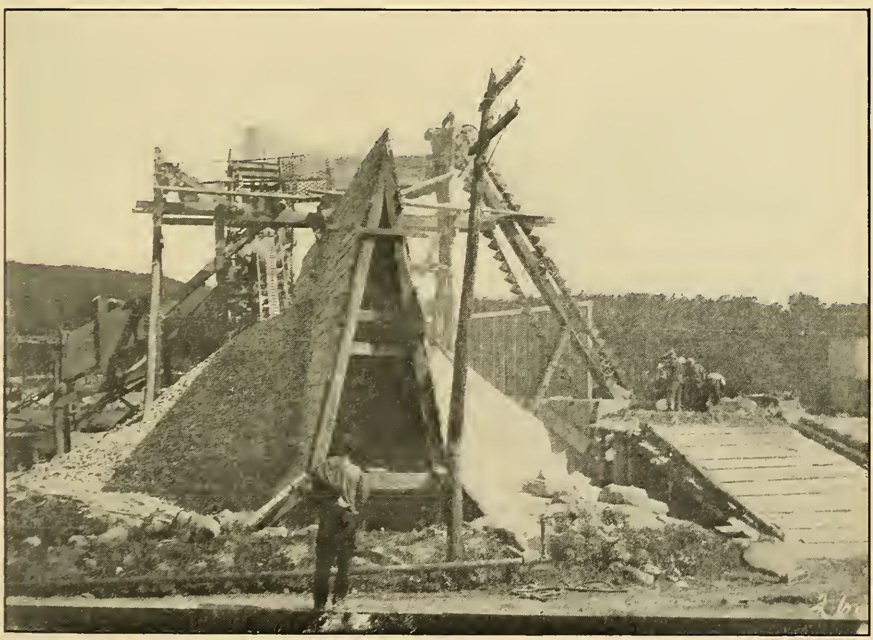


Fig. 18. View of Crusher and Screening Plant.

Fig. 19. View of Concrete Plant.

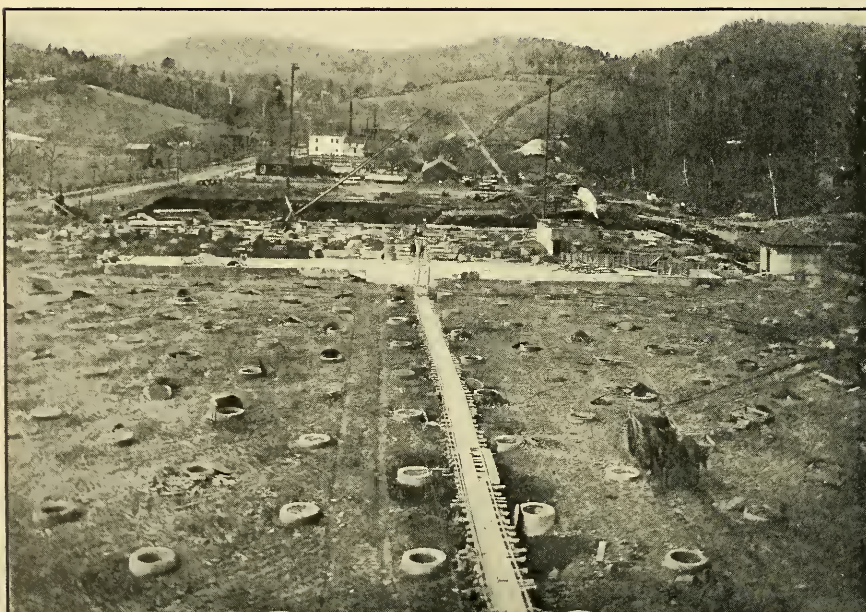


Fig. 20. View showing Derricks for Handling Concrete.

would have necessitated the completion of the entire filter concrete in seventeen working days. As a matter of fact, 125 to 150 cu. yd. per day was a large day's work and represented the contents of a considerable area of filter in addition to the use of an extensive amount of forms. The installation of a simple screening plant at the gravel pit to separate the sand and gravel which could then be hauled as needed to one or two ½-yd. portable mixers located within reach of the derricks would have been a far more economical, sensible and equally serviceable arrangement.

A serious objection to the type of plant used is the possibility of frequent delays resulting from breakdowns in any part of the mechanical system, inasmuch as the operation of one part of the plant depends upon the successful operation of each other part. The breaking of a rope, wheel or bolt in almost any part of the plant resulted in the suspension of concrete work until the repairs were made. In the writer's opinion, a safe rule to follow in such matters when economy is desired is to select the very simplest mechanical arrangement of plant that will produce the required daily output and in general to avoid elaborate installations unless the requirements of progress demand outputs beyond the capacity of the simple methods.

The area covered by the filters was 546 ft. long and 260 ft. wide. It was deemed advisable to employ two derricks for placing the concrete in preference to a traveling cableway which is quite commonly used for the purpose on similar types of construction. The considerations which led to the adoption of the derrick method were as follows:

The cost of a traveling cable machine equipment is much greater than that of the double derrick installation.

The cable arrangement admits of placing concrete in only one narrow transverse zone at a time, while the derricks may be used to deposit concrete at any point within the circle of their swings.

The derricks could be used in setting and removing forms, easily transferring them from one filter to the next, while it would not be practicable to utilize the cableway for this purpose.

The derricks were more likely to be of future service or could be more readily disposed of on the completion of the work than the cable plant.

The double derrick installation insured the work against delay from breakdowns, whereas a single cable outfit might easily suspend concrete work frequently while undergoing repairs.

The two derricks could handle the concrete as fast as a single cable could and, in any event, could place it as rapidly as it was required to be placed and as fast as the concrete plant could deliver it.

Nothing which occurred has altered the original opinions as outlined above, and the derrick method of handling was considered a fortunate selection.

Two ordinary contractors' guy derricks with 70-ft. masts and with booms spliced to 80 ft. were erected on small timber towers tall enough to clear the finished roof level of the first filter built. They were located on the longitudinal center line of the filter and were equidistant from the two end walls of the same. Each filter was 260 ft. long by 91 ft. wide and, with this arrangement, the two derrick booms not only covered the entire area of the filter, but each boom could reach 34 ft. into the second filter and also beyond the end walls, where they were of frequent service in handling heavy piping or loading and unloading teams. The swings of the two booms crossed each other in the center of the filter and each was capable of reaching the service track from the concrete tower, which approached very closely the line of the easterly filter wall.

Concrete was delivered by the service cars to each derrick, the empty bucket being landed on one end of the car and the full bucket removed from the other end. Excelsior bottom-dump buckets were used.

When the derrick had completed the placing of concrete required to construct its half of the first filter, it was moved forward to a similar position in the second filter and received its concrete by means of an extension of the service track laid over the finished roof of the first filter. This process was repeated with each derrick for the six filters. During the construction of the first filter, the hoisting engines operating these derricks were located on the ground outside of the filters, but from this point on they followed the derricks, resting on top of the completed roof. After the third filter had been completed a change of method was adopted. The use of supporting towers was abandoned and the derricks thereafter were moved ahead on the roof as soon as the same was completed to the limit of their reach.

These derricks were also utilized at times for loading teams with concrete to be hauled to the various outside structures, and in a few cases they were able to dump concrete within easy shoveling or wheeling distance of its destination. A view illus-

trating the location and operation of these derricks is shown in Fig. 20.

The detailed cost of this concrete plant was as follows:

COST PER CUBIC YARD FOR CRUSHER AND CONCRETE PLANT.

Transporting to Work.

13 282 cu. yd.

	Per. Cu. Yd. of Concrete Mixed.	
Freight of plant to Westfield	$0.0139	
Cost of unloading plant from cars	0.0148	
Cost of teaming plant to work	0.0161	
Total cost of landing on job		$0.0448
Final Removal of Plant.		
Cost of labor dismantling and loading	$0.0302	
Cost of teaming to railroad	0.01	
Cost of freight returning	0.0043	
Total cost of removing plant		0.0445
Erecting and Maintaining Crusher and Concrete Plant.		
Cost of labor	$0.1725	
Cost of materials and supplies	0.1139	
Cost of miscellaneous teaming	0.0054	
Total cost of erection and maintenance of plant		0.2918
Cement Store House, 50 ft. by 25 ft.		
Cost of materials used	$0.0205	
Cost of labor building	0.012	
Total cost of cement house		0.0325
Erecting, Moving and Removing Derricks and Hoisters.		
Cost of labor	$0.1008	
Cost of miscellaneous supplies	0.0033	
Cost of miscellaneous teaming	0.0011	
Total cost on derricks		0.1052
Depreciation on Plant.		
Cost of depreciation on concrete plant	$0.1003	
Cost of depreciation on crusher plant	0.1370	
Total depreciation		0.2373
Carried forward		$0.7561

Brought forward		$0.7561
Coal and Oil used in Mixing and in Operating Derricks.		
Cost of coal	$0.1222	
Cost of oil	0.011	
Total cost		0.1332
Grand total cost of crusher and concrete plant		$0.8893

Comment on above figures: The above total of $0.89 per cu. yd. of concrete mixed, chargeable alone to the item of planting the concrete end of the work, illustrates forcibly the point previously made concerning the relative economy of different types of plant. It will be noticed that it would require at least 100 000 cu. yd. of concrete to have rendered this plant anything like an economical selection.

The cost of removing the plant on the completion of the work is practically the same as that of originally delivering it. The larger labor item for removing is due to the additional expense of demolishing timber and other structures in connection with the removal, whereas the original labor of delivery included only that of unloading from cars and from teams. The cost of freight for removing is much less than for delivering because a large part of the plant was sold on completion of the work and delivered f.o.b. cars at Westfield.

The cost of labor for erecting and maintaining was larger perhaps than it should have been, amounting in the aggregate to about $2 300. Of this amount $1 560 was contracted in the original installation of this plant and the balance in removing, extending and repairing during the period of its use. The crew employed on this part of the work was not particularly efficient, as the work was naturally done during the early period of organization.

The total expense chargeable to the erection, moving and final removing of the derricks was about $1 400. As the two derricks were each erected once, moved five times and removed once, there were fourteen independent handlings costing an average of $100 for each handling of each derrick. This is, of course, a high cost for such work, but is partly explained by the fact that for the first three filters built it was necessary to construct and erect the timber supporting towers previously referred to, and was also due in part to the cost of a rigger at $5.00 per day who was employed permanently on the work and when not actually moving derricks was charged with examining guys, fastenings, etc., and supervising their use, his entire time

being charged against this item. Although it may at first sight appear needlessly extravagant to employ so high priced a man with so comparatively little to do, the fact that not one serious accident occurred on the entire work is of itself a justification of the expense.

Preparation of Concrete Stock.

Cement.— A peculiar situation arose on this work with respect to the cement. It was the original intention to use the Atlas brand, and shipments of several cars were received preparatory to starting concrete work. The several car loads were subjected to the required tests, both neat and with standard Ottawa sand, and in every case far exceeded the requirements of the specifications in all respects. The first attempt to use this cement in the work, however, resulted in an almost entire lack of setting quality on the part of the concrete. Additional tests were made in the laboratory which checked the original ones and it was then discovered that the local sand in use, although to all appearances excellent in quality, contained some agent antagonistic to the cement. Washing the sand gave only slightly increased strength results. The addition of an acid solution intended to neutralize any possible alkaline agent which the sand might contain also resulted in only a very slight improvement. When, however, an alkaline solution (caustic soda) was added, very material improvement was manifested, indicating the apparent presence of an acid of some kind. An experiment was then tried to determine the effect of introducing into the standard sand a small amount of sap squeezed from the pine and chestnut roots which were prevalent in the local sand pit. The briquettes made from the sand so treated developed the same characteristics that had marked those made with the local sand, thus apparently establishing a connection between these roots and the cement troubles. It was found that these roots penetrated the sand bank more or less to a depth of from 16 ft. to 18 ft., and that below that depth the sand gave fairly good results, although hardly up to requirements. The locality was searched for a more satisfactory sand but without success. Acting on the suggestion of Mr. Hazen, consulting engineer of the work, experiments were made to determine the relative effects of this sand upon different brands of cement. Some eight or ten standard brands were selected for the purpose and the briquettes made therefrom gave widely varying results. Out of this number of

different brands a few developed more than the required strength, while the majority were absolutely unsatisfactory. The Vulcanite brand was selected as the most satisfactory for use with the sand and was subsequently used throughout the work.

Sand and Gravel. — The sand and gravel pit was located in a side hill on land belonging to the city, at a distance of about a mile uphill from the work. It was conveniently located with respect to the road so that small cars could be loaded at the face of the pit, run out on a short trestle and dumped into a hopper at the side of the road from which teams were filled. The pit contained a large proportion of gravel, much of which ran very large, even to fair-sized bowlders. The sand constituted about two thirds of the total volume of the bank and was rather coarse. In fact, the bank was a much better gravel than a sand bank. However, there was no better pit available within reasonable hauling distance from the work, and while the coarseness of the sand had a marked effect at times upon the consistency of the concrete, it gave in general satisfactory results. It was helped considerably by the fact that it was screened simultaneously and in the same screen with the product of the stone crusher so that the stone dust was mixed with it. Fig. 22 shows the general character of the sand and gravel pit. The material as excavated from the sand and gravel pit was teamed to the crusher and screening plant and there shoveled as previously described to the bucket elevator, the large gravel and stones being diverted into the crusher to add to the crushed stone product, while the gravel and sand were elevated with the cracked stone and dust, separated by the revolving screen and delivered to their respective storage piles.

Crushed Stone.— Since gravel constituted only about one third of the volume hauled from the sand and gravel pit, it was necessary to augment the gravel supply by the addition of enough broken stone to supply the deficiency. Stone for this purpose was secured from a variety of sources, some from stone walls in the immediate vicinity, some from small stones rejected from the embankment fill at the dam and some from the many bowlders which required blasting in their removal from the General Excavation. All of this stone was loaded by hand into the teams and hauled to the crusher, an average distance of possibly 800 ft. Some of it required sledging, perhaps 20 per cent. The teams dumped on a platform which was level with the top of the crusher and stone was fed by hand to it. The situation did not admit of the automatic return of the tailings, but they were caught in a

hopper from which they were subsequently reloaded and teamed to the crusher. The daily output of the crusher was not obtainable, as it was complicated more or less by the introduction of the gravel feature.

The elevator was equipped with 14-in. buckets, and was 34 ft. long from center to center of sprockets. It was driven from the crusher by means of a 6-in. belt on a 24-in. pulley, and an E No. 88 sprocket chain system operated both the elevator drive and the 42-in. revolving screen. The screen was of the punch-plate variety and consisted of an 8-ft. section perforated with $\frac{3}{8}$-in. holes for removing the sand and dust and another 8-ft. section perforated with $2\frac{1}{2}$-in. holes for passing the gravel and broken stone. The $\frac{3}{8}$-in. section of the screen was built square in cross section, instead of cylindrical as is customary, the supposition being that it would screen more effectively. As a matter of fact, however, it was far less efficient than a cylindrical section would have been, as it tended to raise and dump the material in a mass instead of scattering it over the area of the perimeter. This action resulted in the frequent plugging of the holes, especially if the sand was at all damp. It also introduced an irregular jerky motion to the screen and thus caused a severe back-lash on the driving chains. This back-lash, together with the strains due to the length and size of the elevator, caused considerable chain troubles, and in another similar installation a heavier pattern of driving chain would be preferable.

The crusher, elevator and screen were driven by a 40-h.p. Brown gasoline engine. The difficulty of obtaining a boiler within a reasonable time, which would conform to the required Massachusetts standard, made it necessary to adopt some other power than steam. This engine was unnecessarily large for the work it had to do and undoubtedly a 25-h.p. engine would have been sufficient, but it was at first intended to run additional apparatus from this engine, the idea being later abandoned. Outside of the additional first cost involved, this surplus power, of course, cost practically nothing. In fuel consumption and operating costs this engine was very economical and after its many peculiarities and corresponding remedies had been discovered, gave general satisfacton. The following figures show the cost of securing and preparing the cement, sand, gravel and stone entering into the concrete work.

COST OF CEMENT, SAND AND STONE PER CUBIC YARD OF CONCRETE USED.

13 282 cu. yd.

Cement cost $1.34 per bbl. net, f.o.b. cars at Westfield.
Cement cost $1.69 per bbl. net, delivered in cement shed.

	Per Cu. Yd. of Concrete Placed.	
Cement.		
Cost of cement in cars	$1.54	
Cost of teaming to work	0.375	
Cost of labor unloading and storing	0.035	
Total cost of cement		$1.95
Sand and Gravel.		
Cost of labor at pit and at screen	$0.237	
Cost of teaming from pit	0.265	
Total cost of sand and gravel		0.502
Crushed Stone.		
Cost of labor picking up stones and feeding crusher	$0.2256	
Cost of teaming stone to crusher	0.14	
Cost of gasoline and oil operating crusher	0.0497	
Cost of miscellaneous supplies	0.0017	
Total cost of crushed stone		0.417
Grand total cost of concrete stock per cu. yd		$2.87

Comment on above figures: The mixture required for this work, aside from that of a small quantity used in reinforced concrete, was as follows:

1 bbl. cement.
11 cu. ft. sand.
19 cu. ft. stone.

This mixture gave, with the materials used, a batch of 23.5 cu. ft., or 1.15 batches to a cubic yard of concrete.

On the basis of the sand and gravel, consisting of two-thirds sand and one-third gravel, there were about 9 300 cu. yd. of the combined materials loaded, hauled and screened; and the above figures would, therefore, indicate a cost of $0.72 for each cubic yard of sand or gravel so loaded, hauled and screened. Owing to the necessity of deep stripping (about 3 ft.) at the pit to remove the more objectionable of the roots, the cost of loading this material was high. Ten trips was the usual performance of a double team hauling about 1.5 cu. yd. to each load, so that the cost per cu. yd. of hauling was about $0.40, leaving $0.32 to cover the cost of stripping, loading and shoveling on to the elevator.

Based on the above assumption of the quantity of gravel used, there would remain 7 600 cu. yd. or 10 260 tons of crushed

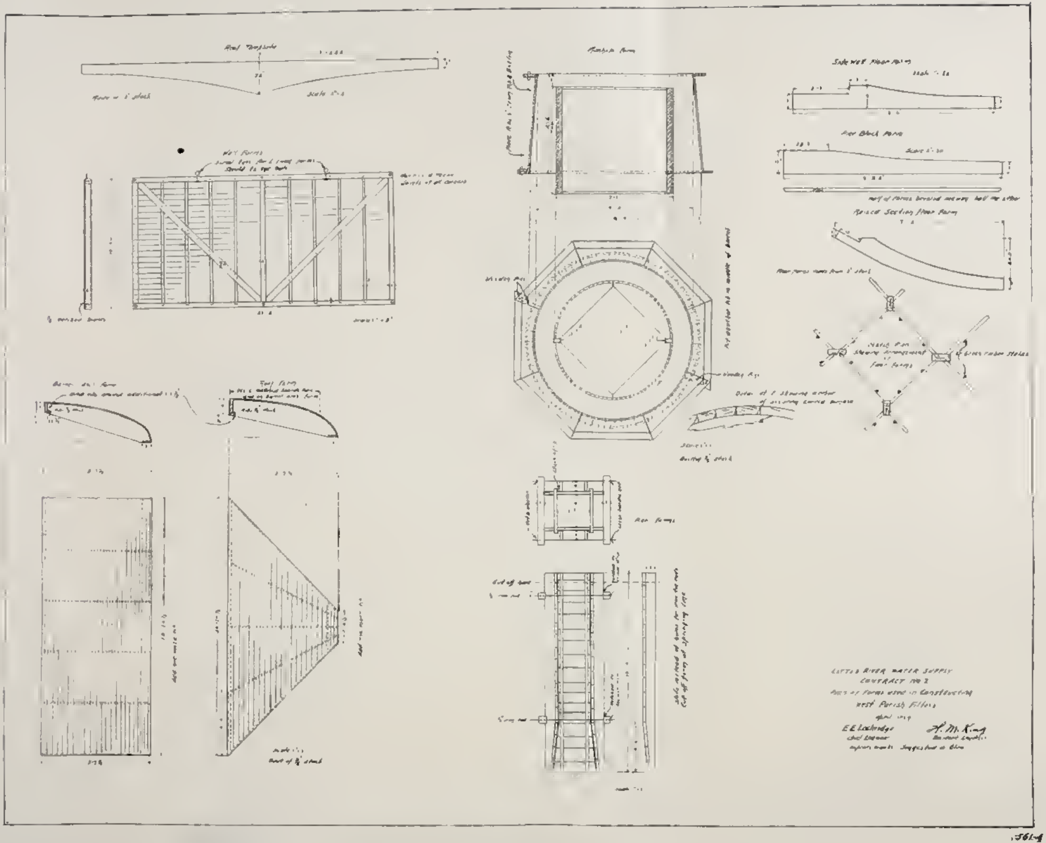


FIG. 23.

stone which must have been supplied by the crusher to complete the required amount of aggregates. At the above cost figures, the cost per ton of crushed stone would be as follows:

Cost per Ton of Stone Actually Crushed.

10 260 tons.

Cost of labor loading teams and feeding crusher..	\$0.29 per ton
Cost of teaming to crusher....................	0.18 per ton
Cost of fuel and supplies......................	0.07 per ton
Total cost of crushing......................	\$0.54 per ton

From the two foregoing articles it will be apparent that before a cubic yard of concrete entered the mixer it had contracted a cost of \$0.89 for its proportional expense of the plant charges, and of \$2.87 for the cost of cement, sand, gravel and stone which it contained. The total of \$3.76 for these two charges is a constant, therefore, to be added to the cost of mixing, placing and form work for each cubic yard of concrete in the work, regardless of its position. This constant will be referred to in the following items as "plant and stock constant."

Filter Floors.

The filter floor was of the common, inverted groined arch type, 6 in. thick at the valleys and 12 in. at the pier points, which points were 13 ft. on centers each way. The floor blocks were, therefore, square in plan and measured 13 ft. on their diagonals. The subgrade was level throughout and the increasing thickness from valley to pier points was obtained by the use of four curved templates, as shown in Fig. 23. These four templates were assembled to form the side forms of the square floor blocks and were in touch at their corner points with the corresponding corners of alternate floor block forms. Concrete was deposited in these alternate blocks and the top surface was formed by screeding over the curved templates which formed the sides. When the concrete in the alternate blocks had attained sufficient set, the surrounding templates were removed and the remaining blocks were completed, using the finished edges of the first blocks as templates upon which to screen. Special templates were necessary where the floors met the surrounding walls, but the same principle of depositing concrete was retained. The details of floor construction are shown in Fig. 3. The concrete used in floor construction was, in general, dumped directly into place by means of the derricks and 1-yd. bottom-dump

buckets, although at times when it became desirable to lay floor in advance of the reach of the derrick, the concrete was dumped on the finished floor at the nearest point to which the boom could reach and was then wheeled to place in barrows. It was often considered advisable to incur this additional expense of wheeling on account of the increased progress attained thereby. Fig. 24 illustrates the method used in placing floor concrete.

Cost of Concrete in Filter Floors.

3 933 cu. yd.

	Per Cu. Yd. of Concrete.	
Forms.		
Cost of forms delivered at Westfield........	$0.08	
Cost of teaming same to work..............	0.008	
Cost of labor handling, placing and removing..	0.132	
Total cost of form work..........................		$0.22
Concrete.		
Plant and stock constant..................	$3.76	
Cost of labor mixing......................	0.18	
Cost of labor placing.....................	0.545	
Cost of miscellaneous supplies..............	0.008	
Cost of proportion of expense of final cleaning up of filters..........................	0.019	
Total cost of concrete and labor thereon.............		4.512
General expense, 12.9 per cent....................		0.614
Grand total cost of this item......................		$5.346

Comment on above figures: A sufficient number of forms was provided to permit concreting an entire floor of one filter. This proved to be an excessive number and one third of the amount would have been ample to have assured the necessary progress, with a saving of $0.05\frac{1}{3}$ per cu. yd. of concrete. These forms cost $0.95 each, or $3.80 per set, and were cut from 2-in. by 12-in. spruce stock.

The cost of mixing covers all labor used in measuring aggregates, feeding cement and operating skip car and mixer. The cost of placing covers all labor employed beyond the mixer, such as the operating of cars on the service track, derrick crews, shovelers, spaders, etc. The cost of placing appears to be high for such simple work, but this is explained by the fact that the time of two men was required constantly screeding the surfaces of the blocks. The occasional extra wheeling in barrows as explained also added considerably to the cost. The above figures represent an average cost of $0.149 per sq. ft. of floor area and

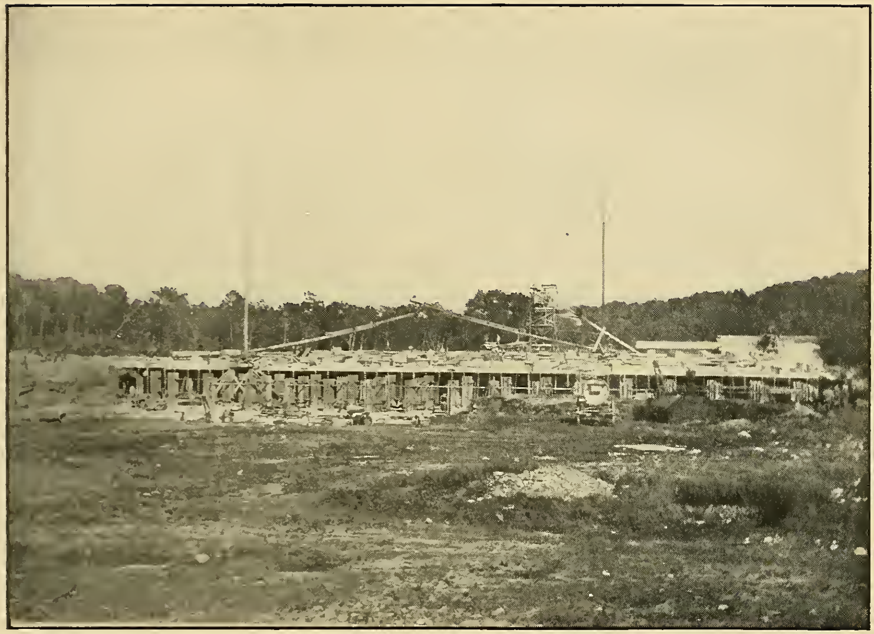


Fig. 21. View of Filters under Construction.

Fig. 22. Sand and Gravel Pit for Concrete Materials.

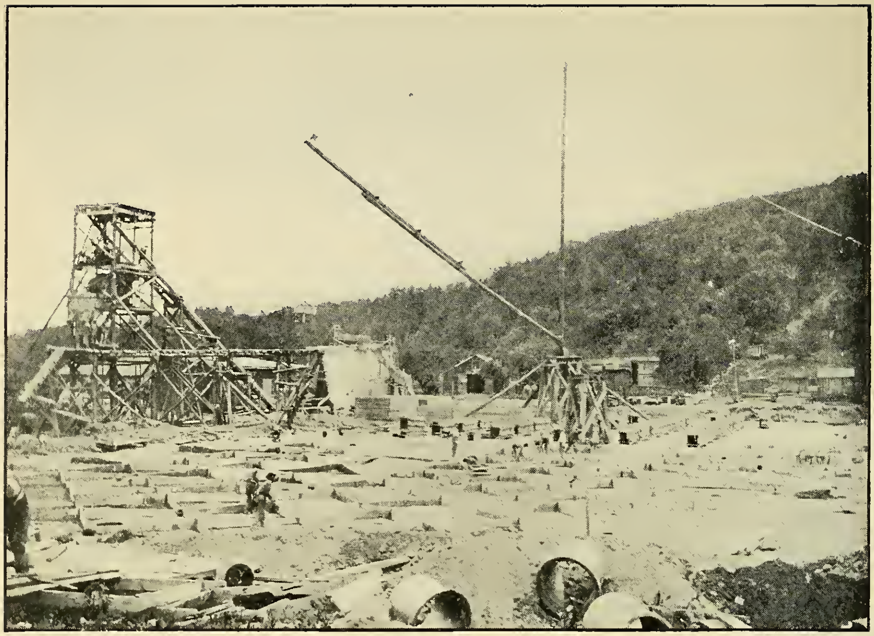


Fig. 24. Method of Placing Filter Floor Concrete.

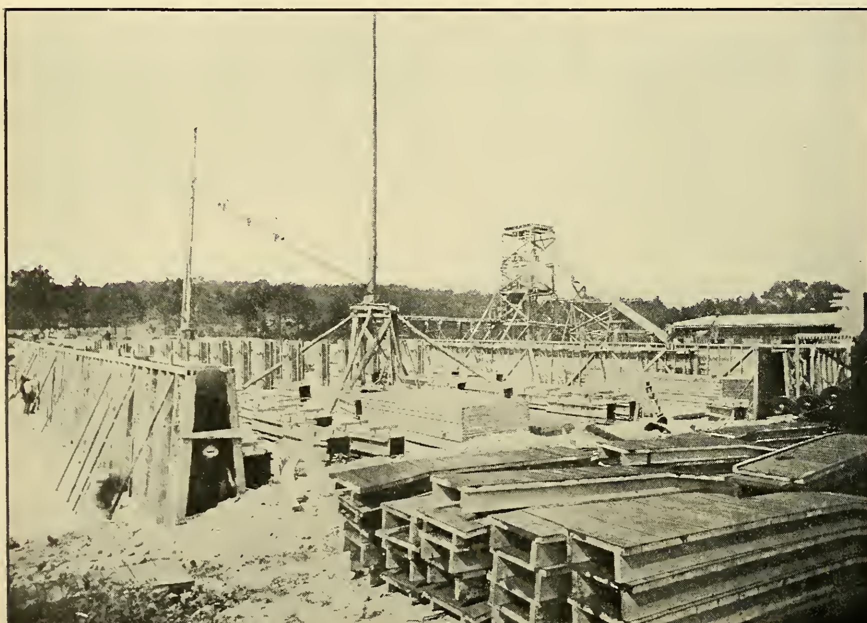


Fig. 25. Method of Placing Filter Wall Concrete.

covers in addition the cost of 50 cu. yd. of concrete extra in each filter, which was used for surrounding the 24-in. central drains.

The contract price for this concrete was......	\$5.50
The maximum price bid was................	9.00
The minimum price bid was................	5.50
The average price bid was..................	7.75

Filter Walls.

The walls as shown in detail by Fig. 3 were about 10 ft. high, 20 in. thick on the top and 29 in. thick at the bottom for the outside walls, while the division walls between the filters were 39 in. thick at the bottom.

The specifications required that all walls should be built in sections 13 ft. in length, so as to distribute possible shrinkage among the several joints and thus minimize its effect.

The forms for these walls were made in panels 10 ft. high and 20 ft. long as shown in Fig. 23. They were of $\frac{7}{8}$-in. matched spruce with 2-in. by 6-in. uprights and a main frame of 4 in. by 6 in. Each panel weighed when in use about 1 500 lb. and was provided with eye-bolts in the top of the frame to allow convenient handling by the derricks. In erecting wall forms a double row of these panels was placed in position by the derricks, carefully lined by hand and wired together with frequent strands of No. 11 galvanized wire. A few outside struts maintained the top line in correct position and wooden spreaders placed between panels assured the correct thickness of wall. These spreaders were, of course, removed as the concrete progressed. Bulkheads of the exact cross section of the wall were accurately placed between forms every 13 ft., each bulkhead containing a vertical roughing piece triangular in shape intended to form a bonding groove in the joint. Alternate sections of wall were then concreted and when set sufficiently the bulkheads were removed and intermediate sections completed, thus making the wall continuous.

In filling the wall sections dumping platforms were employed. These platforms were 13 ft. square, made of 2-in. plank, one edge being supported by the top of the wall form panel and the opposite edge by wooden legs resting on the filter floor. A pitch of about 1 ft. was given the platform toward the wall. This platform was easily moved and placed by means of the derricks, each platform having wire ropes permanently attached to it for the purpose of convenient handling. The contents of the buckets were dumped on these platforms close to the edge nearest the wall, and the mixture being quite wet flowed down the slope of

the platform and into the forms. This method allowed an entire batch to be dumped at one time without straining the forms. A man was required to clean the end of each batch off the platform by shoveling it into the wall. Fig. 25 shows the forms in place and illustrates the method of filling.

When the concrete had obtained a sufficient set the wires were cut and the panels removed by the derricks to be again placed in position for a new length of wall. The use of these large panels and their convenient handling by the derricks simplified the form work materially.

Cost of Concrete in Filter Walls.

2 481 cu. yd.

	Per Cu. Yd. of Concrete.	
Forms.		
Cost of panels, lumber, wire, etc., at Westfield,	$0.69	
Cost of teaming same to work	0.051	
Cost of labor erecting and removing	0.55	
Total cost of form work		$1.30
Concrete.		
Plant and stock constant	$3.76	
Cost of labor mixing	0.173	
Cost of labor placing	0.44	
Cost of miscellaneous supplies	0.017	
Cost of proportion of expense of final cleaning of filters	0.019	
Total cost of concrete materials and labor thereon		4.409
General expense, 12.9 per cent		0.741
Grand total cost for this item		$6.45

Comment on above figures: Wall forms were provided in sufficient number to have concreted the entire four walls of one filter simultaneously. This subsequently proved to have been a serious blunder and half the amount of panels would have been adequate. This mistake in judgment represented, therefore, a waste of $0.34 per cu. yd., or a total amounting to $843. These panels cost $15.54, delivered in Westfield.

The cost of wall form work per square foot of surface covered, exclusive of bulkhead surfaces, was as follows:

Cost of materials	$0.031 per sq. ft.	
Cost of labor erecting and removing	0.024 per sq. ft.	
Total cost		$0.055 per sq. ft.

This would have been reduced at least $0.015 per sq. ft. had only the necessary amount of panels been provided.

The contract price for this work was, per cu. yd.,	$5.50
The maximum price bid was, per cu. yd......	9.00
The minimum price bid was, per cu. yd......	5.50
The average price bid was, per cu. yd........	7.75

Filter Piers.

The piers as shown in Fig. 3 were 20 in. square, with the exception of the lower 2 ft. which tapered to 26 in. They were arranged 13 ft. on centers in either direction and were 9.5 ft. high. A simple and very convenient type of form was used for casting these piers and is shown in detail in Fig. 23. It consisted of four sides each made from 2-in. spruce planks nailed horizontally to two 2-in. by 6-in. uprights. These 2-in. by 6-in. uprights were cut for their lower 2 ft. with a 3-in. bevel which formed the flare called for at this point. The 2-in. lagging of two of the sides was prolonged 2 in. beyond the edges of the other two sides and vertical strips 2 in. wide were nailed to these projections, thus forming cleats against which the other sides rested when under pressure from the inside. Two sets of 4-in. by 4-in. clamps secured by ½-in. bolts held the two wide sides firmly against the edges of the two narrow sides.

In setting these forms, cross lines were chalked on the filter floor, representing the center lines of piers in both directions. These lines were prolonged well outside the area to be covered by the form. A template was made to fit the top of the pier form with projecting arms whose edges also represented the center lines in both directions, and four plumb bobs were suspended from these projecting arms until they just cleared the filter floor. Center marks on the bottom of the forms were set to match the chalk marks and the top of the form was moved one way or another until the four plumb bobs coincided with the projected cross lines. This arrangement assured both the top and bottom of the forms being on exact centers. Once in their proper position, the forms were secured by light bracing from one to another, checker-board fashion.

In filling these forms the same dumping platforms were used as for the walls. They were supported at their corners by four pier forms and these four piers were filled simultaneously by shoveling concrete which was dumped on the platform into them. When the four piers were filled the platform was raised by the derrick, together with any surplus concrete which re-

mained on it and was transferred to another group of four piers. Fig. 26 illustrates the method of filling pier forms. The cost of concrete piers was as follows:

COST OF CONCRETE IN FILTER PIERS.

684 piers, 708 cu. yd.

	Per Cu. Yd.	
Forms.		
Cost of forms delivered on work	$2.65	
Cost of labor erecting and removing	1.123	
Total cost of form work		$3.773
Concrete.		
Plant and stock constant	$3.76	
Cost of labor mixing	0.173	
Cost of labor placing	0.506	
Cost of proportion of expense of final cleaning of filters	0.019	
Total cost of concrete materials and labor thereon		4.458
General expense, 12.9 per cent		1.06
Grand total cost for this item		$9.291

Comment on above figures: One hundred and fourteen pier forms were provided, or enough for one complete filter. This was at least double the number actually required. Each complete form delivered in Westfield cost $14.25. The waste represented by this surplus supply amounted to $1.33 per cu. yd., or a total of $938. The pier forms were subsequently sold for use on another similar contract and were the only portion of the forms on which any salvage was realized. At the above figures the form work cost per square foot of surface covered, as follows:

Cost of materials	$0.042	per sq. ft.
Cost of labor	0.018	per sq. ft.
Total	$0.06	per sq. ft.

Had only the necessary number of forms been supplied, this cost would be reduced by $0.021.

The contract price for this item was	$8.00
The maximum price bid was	12.00
The minimum price bid was	7.00
The average price bid was	9.69

VAULTING.

The vaulting or roof of the filters consisted of groined arches supported on the walls and the piers as shown in Fig. 3.

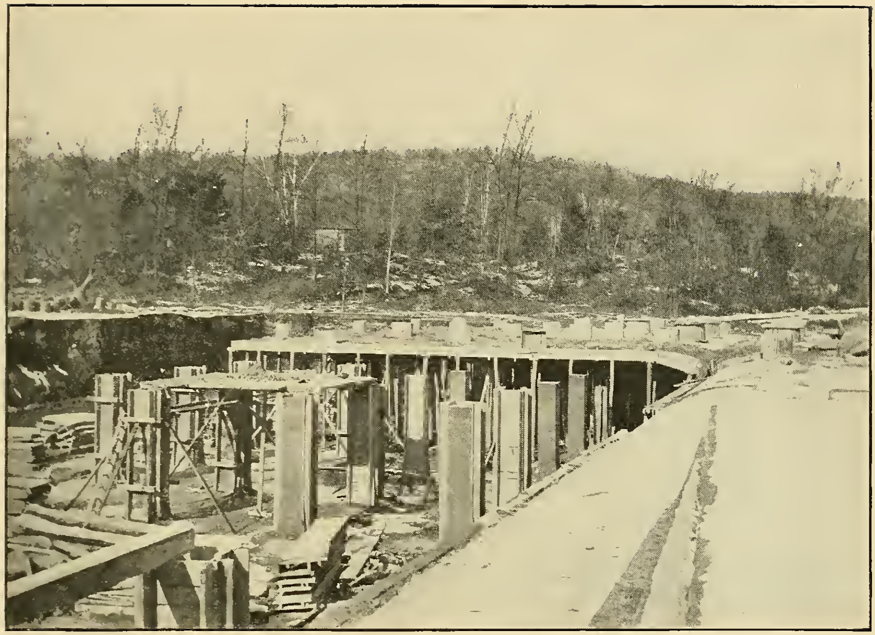


Fig. 26. Method of Placing Filter Pier Concrete.

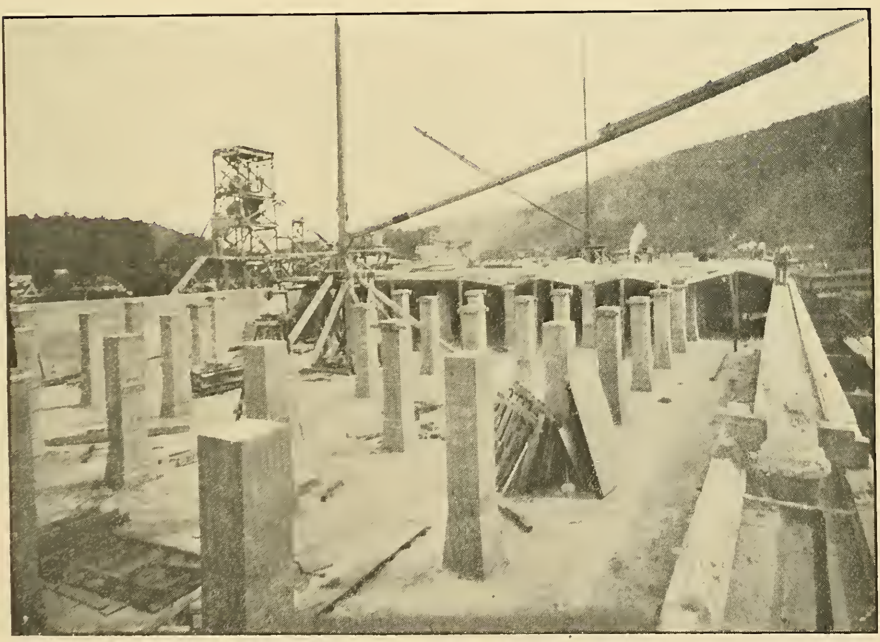


Fig. 27. Method of Supporting Roof Forms.

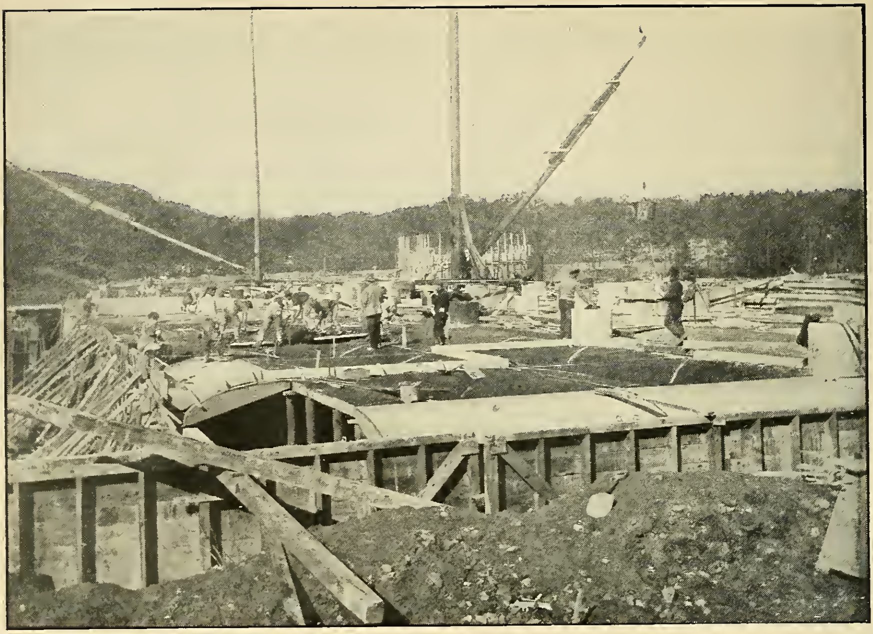


Fig. 28. Method of Placing Filter Roof Concrete.

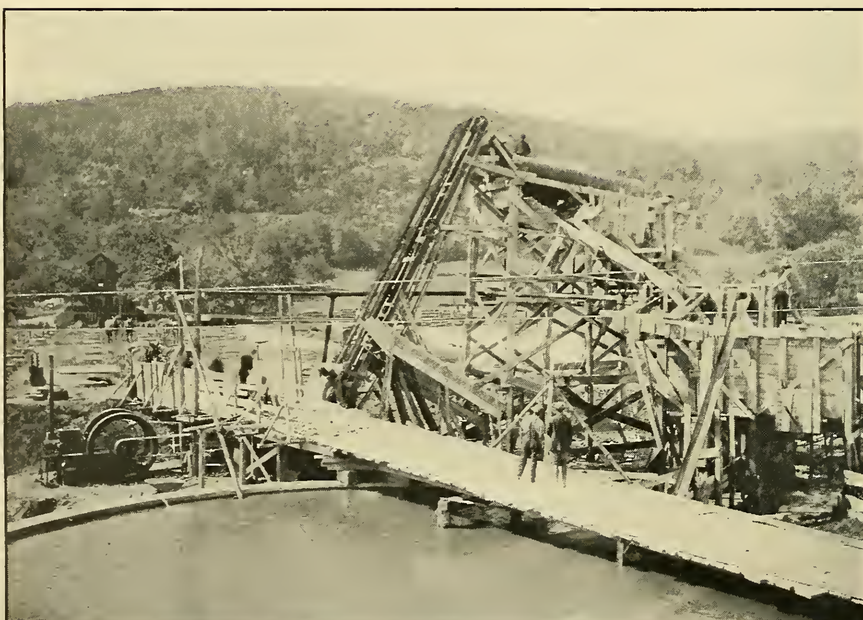


Fig. 30. View of Filter Sand Washing Plant.

The vaulting in general has no reinforcement, is 6 in. thick at the crown and 12 in. at the skew backs, with a rise of 2 ft. between piers. The upper or outer surface of the finished roof forms a series of flat arches in two directions terminating in depressions over each pier.

The details of forms used for the vaulting are shown by Fig. 23. They consisted of sections whose shape was triangular in plan view except that the points of the triangle were cut off to fit the sides of the piers. They were 20 in. wide at the narrow or pier edge and spread out to 13 ft. at the wide or outer edge. Looked at in side view they possess the requisite elliptical curvature conforming to that of the proposed arch intrados between the springing line and the crown. Thus four of these sections, when assembled around the four sides of a pier, formed a section of roof 13 ft. square and extending on all sides half way to each next adjacent pier. Subsequent squares when erected about adjacent piers connected with them and formed a continuous area of roof forms.

The outer edges of these triangular-shaped sections were supported by posts from the filter floor, using for the purpose small saplings cut in the near-by woods. The pier ends of these forms were at first supported upon wooden clamps bolted around the tops of the finished concrete piers and set exactly to springing line grade. In the last two filters constructed, however, these inner edges rested directly on top of the pier forms and both piers and roof were concreted simultaneously. In erecting these forms, four men lifted a section in the air on pike poles, resting its narrow end on the pier support. Two men then held the wide ends with their poles while the others erected the posting which was to carry it. The posts all being cut to one length, no further adjustment was usually required. The method of supporting these forms is clearly shown in Fig. 27. In subsequently striking these forms they were held with pike poles while the posting was knocked out from under them and were then lowered to the floor.

Adjacent to the walls, barrel arch forms were required springing from the wall skew back and meeting the 13-ft. ends of the groined arches.

The openings and cracks which occurred at the joints of the forms were covered with heavy brown paper tacked on to the forms in narrow strips. This paper could be subsequently removed by wetting, or if left alone would peel off in a few days of its own accord.

The dumping platforms previously described were also used in placing the roof concrete, as it was deemed unsafe to dump the buckets directly on top of the arch forms. The platforms were supported by the crown points of the forms and the load was carried directly by the posting under these points. Concrete was shoveled from the platforms into place, a 13-ft. square around the pier being filled in one operation. The upper surface was formed by means of a template or gage shown in Fig. 23. Fig. 28 illustrates the method of placing roof concrete.

A rule was made, and strictly adhered to, providing that at least two lines of roof squares should always remain supported by forms adjacent to every open end, the object being to take up any possible arch thrust which might be transmitted from the finished roof in the rear. It was also deemed prudent to carry a line of incline struts against the outer row of arch forms to prevent pushing out of that section while being filled.

An opening was left at the center of each division wall through which the forms could be carried forward into the next filter after their removal. The cost of the vaulting was as follows:

Cost of Concrete in Filter Roof.

3 673 cu. yd.

		Per Cu. Yd. of Concrete.
Forms.		
Cost of forms and teaming same	$1.055	
Cost of labor erecting and removing	0.704	
Total cost of form work		$1.759
Concrete.		
Plant and stock constant	$3.76	
Cost of labor mixing	0.15	
Cost of labor placing	0.40	
Cost of proportion of expense of final cleaning of filters	0.019	
Total cost of concrete materials and labor		4.329
General expense, 12.9 per cent		0.782
Grand total cost of this item		$6.87

Comment on above figures: The specifications required that roof forms for one complete filter should be provided and this requirement was complied with. It is probable that one half this amount of forms would have sufficed, although the forms used were in rather bad shape at the completion of the work. Had they been originally made stronger it is probable that they could have been used a much greater number of times without

serious deterioration. Each triangular section cost $7.39, and each barrel section $8.21. Had it been possible to complete the work with one half the number of forms, a saving of $1 940, or $0.53 per cu. yd., would have resulted. The form cost figures would indicate the cost per square foot of surface covered to have been as follows:

Cost of materials	$0.027 per sq. ft.
Cost of labor erecting and removing	0.018 per sq. ft.
Total	$0.045 per sq. ft.

The total cost per sq. ft. of finished roof was $0.175.

The contract price for this work was	$8.00
The maximum price bid was	12.50
The minimum price bid was	7.00
The average price bid was	9.69

Aërator.

The aërator is a circular concrete tank 50 ft. in internal diameter, with a level floor 12 in. thick and walls 9.75 ft. high and 24 in. thick. A 16-in. and a 24-in. cast-iron pipe enters through the bottom of the wall from the office and laboratory building and delivers the raw water after sedimentation. These pipes turn upward at right angles in the center of the aërator and terminate with perforated flanges. In addition to these pipes a 4-ft. by 5-ft. reinforced conduit enters through the wall from the wet well of the office and laboratory building and is intended for the ordinary means of supply when aëration is not desired. A 42-in. steel pipe leaves the aërator through the wall on the opposite side from the supply and distributes water to the filters. A waste way consisting of a 4-ft. by 5-ft. reinforced conduit connects the aërator with a near-by brook and terminates inside the aërator in a small chamber shut off from it by a set of stop planks. By adjusting the height of these stop planks the desired water level is assured in case of the failure of other regulating devices upon which dependence is ordinarily placed.

When the excavation for this structure was completed the floor was laid and finished in one operation. Concrete was obtained at the mixer by a chute delivering into bottom-dump wagons. These wagons were hauled from the mixer to the aërator site and the concrete dumped directly into place, the teams driving down into the excavated pit. This concrete, therefore, required only leveling and the smoothing of its surface.

When the floor concrete was set sufficiently, circular ribs made from segments cut at the mill were assembled and accurately centered. The inside ribs were cut convex, while the outer ribs were concave in shape. These rings were lagged with 2-in. lagging set vertically. The corresponding inside and outside ribs were wired together to resist the spreading strains of the concrete during the operation of placing. The bottom half of the outer face was concreted directly against the earth bank so that forms were required on this side for only the upper half of the wall. The wall was reinforced with three hoops of $\frac{3}{4}$-in. twisted rods spaced equidistant from top to bottom. The cost of the concrete work in this structure was as follows:

Cost of Concrete in Aërator Floor.

91 cu. yd.

Cost of plant and stock constant	$3.76 per cu. yd.	
Cost of labor mixing................	0.132 per cu. yd.	
Cost of labor placing................	0.311 per cu. yd.	
Cost of teaming from mixer..........	0.133 per cu. yd.	
Total cost for concrete....................		$4.336 per cu. yd.
General expense, 12.9 per cent.............		0.564
Grand total cost for this item..............		$4.90 per cu. yd.

The contract price for this work was	$5.50
The maximum price bid was........	9.00
The minimum price bid was........	5.50
The average price bid was..........	7.75

Cost of Concrete in Aërator Wall.

131 cu. yd.

Forms.

Cost of forms, nails, etc.	$0.99 per cu. yd.	
Cost of labor erecting and removing.	0.583 per cu. yd.	
Total cost of forms....................		$1.573 per cu. yd.

Concrete.

Plant and stock constant......	$3.76 per cu. yd.	
Cost of labor mixing..........	0.12 per cu. yd.	
Cost of labor placing..........	0.687 per cu. yd.	
Cost of teaming from mixer....	0.181 per cu. yd.	
Cost of finishing surface.......	0.122 per cu. yd.	
Total cost of concrete.....................		4.87 per cu. yd.
General expense, 12.9 per cent.............		0.831
Grand total cost for this item..............		$7.274 per cu. yd.

The contract price for this item was..........	$8.00
The maximum price bid was................	13.00
The minimum price bid was................	8.00
The average price bid was.................	11.46

Comment on above figures: The cost of lumber is large on account of the necessary use of a sufficient amount of lumber to form the entire wall at one time. The cost figures for forms indicate a cost per sq. ft. of surface covered as follows:

Cost of materials...............	$0.045	per sq. ft.
Cost of labor erecting and removing	0.028	per sq. ft.
Total.......................	$0.073	per sq. ft.

No allowance is here made for second-hand value of the lumber. The cost of placing included the entire charge of a five-dollar-a-day foreman, or a trifle less than 4 cents per cu. yd. The concrete after being hauled from the mixer was dumped on platforms adjacent to the walls to be filled and partly shoveled into place and partly wheeled in barrows on elevated runways. The finish referred to consisted in rubbing the surface with a carborundum brick and water as soon as the forms were stripped. The cost figures given for this feature are equivalent to a cost of $0.006 per sq. ft. of surface finished.

Building Foundations.

The foundations of the office and laboratory building, together with that of the regulator house, required the placing of a total of 450 cu. yd. of concrete. The walls were mostly 2 ft. in thickness. The substructure of the regulator house is divided into several pockets or wells into which the water pipes from the filters discharge. The construction of these wells necessitated much cutting of forms, especially so because of the numerous pipes passing through the several walls, all of which required special fitting.

The specifications required the entire foundation walls of the regulator house to be placed in one operation, the purpose being to avoid all danger of leakage through joints. This provision necessitated the use of enough lumber to form the entire surface of the walls at one time. The office and laboratory building foundation was built in two parts, permitting the use of the forms a second time. Concrete for the regulator house foundation was dumped by one of the derricks on a platform adjacent to one side of the foundation and was deposited in the

forms by shoveling or was wheeled in barrows. Concrete for the office and laboratory building foundation was teamed from the nearest derrick, dumped on a platform and placed as described for the regulator house foundation.

The cost of these building foundations was as follows:

Cost of Concrete in Regulator House Foundation.

271 cu. yd.

		Per Cu. Yd. Concrete.
Forms.		
Cost of lumber, nails, etc	$0.234	
Cost of labor erecting and removing	0.931	
Total cost of forms		$1.165
Concrete.		
Plant and stock constant	$3.76	
Cost of labor mixing	0.11	
Cost of labor placing	0.532	
Total cost of concrete		4.402
General expense, 12.9 per cent		0.718
Grand total cost of this item		$6.285

Cost of Concrete in Office and Laboratory Building Foundation.

		Per Cu. Yd. Concrete.
Forms.		
Cost of lumber, nails, etc	$0.234	
Cost of labor erecting and removing	0.98	
Total cost of forms		$1.214
Concrete.		
Plant and stock constant	$3.76	
Cost of labor mixing	0.15	
Cost of labor placing	0.796	
Cost of teaming from nearest derrick	0.101	
Total cost of concrete		4.807
General expense, 12.9 per cent		0.777
Grand total cost of this item		$6.798

Comment on above figures: The lumber used for forms in this work was about one half new, while the balance had been used before on other parts of the work. The new lumber only is charged in the above figures. The form costs indicate a cost per square feet of surface covered as follows:

For Regulator House Foundation.

Cost of materials	$0.0113 per sq. ft.
Cost for labor	0.045 per sq. ft.
Total	$0.0563 per sq. ft.

Office and Laboratory Building.

Cost for materials	$0.013	per sq. ft.
Cost for labor	0.057	per sq. ft.
Total	$0.07	per sq. ft.

The high labor cost per sq. ft. for the office and laboratory building foundation can be explained only by the assumption that the labor was much less efficient in this case than that of the regulator house foundation, the latter being really the more difficult to build of the two.

The contract price for this work was	$5.50
The maximum price bid was	9.00
The minimum price bid was	5.50
The average price bid was	7.75

Concrete Cut-Off Wall.

This work consists of the building of a 3-ft. wall running longitudinally under the center of the earth dam. It was carried to ledge in all cases and varied in depth from 1 to 25 ft. Its finished top extended only about 2 ft. above the natural surface of the ground. There was also included, in connection with this work, 200 cu. yd. of concrete deposited around the 42-in. steel pipe lines at the point where they passed through the ledge immediately under the dam. As the concrete was all buried beneath the fill, no attempt was made to secure smooth form work, and in general rough boards or planks were used to confine the masonry to its proper width. Small stones and bowlders were imbedded in this concrete as freely as its dimensions and consistency would allow, the stones being plentiful in the surrounding locality. A small amount of this concrete was mixed by hand during the early stages of the work and prior to the completion of the concrete plant. The bulk of it, however, was teamed from the mixer, an average distance of about 1 200 ft., and was dumped upon platforms from which it was shoveled into place. Its cost was as follows:

Cost of Concrete Cut-off Wall in Dam and around Pipes.

1 155 cu. yd.

Forms.

Cost of lumber, nails, etc.	$0.138 per cu. yd.	
Cost of labor erecting and removing forms	0.17 per cu. yd.	
Total cost of forms		$0.308 per cu. yd.
Carried forward		$0.308 per cu. yd.

Brought forward		$0.308 per cu. yd.
Concrete.		
Plant and stock constant	$3.76 per cu. yd.	
Cost of labor mixing	0.124 per cu. yd.	
Cost of teaming from mixer	0.218 per cu. yd.	
Cost of placing	0.544 per cu. yd.	
Cost of miscellaneous charges	0.052 per cu. yd.	
Total cost of materials and labor thereon		4.698 per cu. yd.
General expense, 12.9 per cent.		0.646
Grand total cost of this item		$5.652 per cu. yd.

The contract price for this item was	$5.50
The maximum price bid was	9.00
The minimum price bid was	5.50
The average price bid was	7.75

Reinforced Concrete Conduits.

Mention has previously been made of certain reinforced concrete conduits 4 ft. by 5 ft. in cross-section. The greater portion of this conduit work was necessitated in the construction of the circulating conduit, extending from the inlet pipe through the dam to the upper end of the sedimentation basin. This piece of conduit was approximately 600 ft. in length and was built in the side hill forming the westerly wall of the basin. In addition there were 125 ft. of conduit of the same design used for connecting the aërator with the wet well of the office and laboratory building and with the brook.

The design was of the horseshoe type, 4 ft. wide and 5 ft. high. It was built with plumb side walls and an elliptical arch. The invert and arch were each 6 in. thick and the walls averaged 10 in. The volume of concrete per lin. ft. was approximately 0.5 cu. yd. One-half inch square twisted rods, spaced 15 in. on centers, were placed circumferentially; and in parts of its length ½-in. longitudinal reinforcement was used in the bottom and the walls.

About one half of this work was built with concrete teamed from the mixer, and shoveled into the forms, the average distance of teaming being about 1 000 ft. The last half of the circulating conduit was mixed by hand, using materials teamed from the stock piles at the crusher.

Blaw collapsible steel centers were used in part, together with an equal amount of wooden centers. The steel centers produced a much smoother finished surface, but in the cost of handling showed no special advantage over the wooden forms, as in this instance both types were comparatively light and easy to handle.

The cost of this conduit work was as follows:

COST OF 4 FT. BY 5 FT. REINFORCED CONCRETE CONDUITS.

725 ft., 326 cu. yd.

Forms.		
Cost of lumber, Blaw centers, etc.	$0.302 per cu. yd.	
Cost of labor erecting and removing forms	0.972 per cu. yd.	
Total cost of forms		$1.274 per cu. yd.
Concrete.		
Plant and stock constant	$3.76 per cu. yd.	
Cost of labor mixing and placing	1.516 per cu. yd.	
Cost of teaming concrete and stock...	0.56 per cu. yd.	
Total cost of concrete materials and labor...		5.836 per cu. yd.
General expense, 12.9 per cent		0.917 per cu. yd.
Grand total cost of this item		$8.027 per cu. yd.

Comment on above figures: Based on the cost of form work as shown above, the cost per sq. ft. of surface covered was as follows:

Cost of lumber, lease of centers, etc	$0.007 per sq. ft.
Cost of labor erecting and removing	0.023 per sq. ft.
Total cost of forms	$0.03 per sq. ft.

The low cost per sq. ft. as compared with the other cases given is due mainly to the frequency of re-using and to the fact that common labor could be used more generally, thus dispensing with expensive carpenter labor. The cost of mixing and placing was high as conditions were poor for economical handling. The high cost of teaming is partly accounted for by the fact that the greater part of the hand-mixed concrete was also teamed to place in the work, there being but one point available for mixing the concrete. The cost of the completed conduit exclusive of reinforcement was about $4.00 per lin. ft.

The contract price for this work was, per cu. yd.,	$8.00
The maximum price bid was, per cu. yd	13.00
The minimum price bid was, per cu. yd	8.00
The average price bid was, per cu. yd	11.465

REINFORCING STEEL.

There were required in the 1 032 cu. yd. of reinforced concrete, 48 014 lb. of twisted steel bars. Of this amount 38 000 lb. were of $\frac{3}{4}$-in. size in comparatively long lengths and required

little or no bending. The $\frac{1}{2}$-in. and $\frac{3}{8}$-in. sizes were used in the conduit work and were, of course, easily bent. The cost of the steel reinforcement was as follows:

Cost of steel f.o.b. Westfield...........	$0.0168	per lb.
Cost of teaming to work...............	0.0012	per lb.
Cost of handling, bending and placing...	0.0015	per lb.
Total cost of steel in place...........	$0.0195	per lb.
General expense, 12.9 per cent.......	0.0025	per lb.
Grand total cost of steel reinforcement	$0.022	per lb.

The contract price for this item was, per lb	$0.03
The maximum price bid was, per lb..............	0.08
The minimum price bid was, per lb..............	0.03
The average price bid was, per lb................	0.0443

Filtering Materials.

As indicated by the title of this paper, the filtering agency employed in the operation of the plant is sand. The contract plans called for a layer of sand of certain specified requirements 3 ft. in thickness, covering the entire area of each filter. For the purpose of properly collecting the filtered water after it has percolated through the sand and for delivering it to the outlet drains, a bed of gravel 12 in. in thickness arranged in three layers of different sizes and surrounding 10-in. split tile lateral drains was deposited over the filter floor in advance of the sand layers. The lower 7 in. of the bed of gravel consisted of stones larger than 1 in. in diameter and with few larger than 2 in. The next $2\frac{1}{2}$ in. of thickness contained stones which had passed a 1-in. screen and had been retained on a screen of $\frac{3}{8}$-in. mesh. The top $2\frac{1}{2}$-in. layer of gravel contained stones which had passed a $\frac{3}{8}$-in. mesh and varied in diameter from $\frac{3}{8}$-in. size down to that of the coarsest grains of sand. There were, therefore, including the sand, four different grades of material required for this purpose.

The specifications in describing the necessary requirements of the sand provided that grains exceeding 5 mm. should be excluded and that not more than 1 per cent. should be less than 0.13 mm., that its effective size should lie between 0.25 mm. and 0.35 mm. and that its " uniformity coefficient " should not exceed 3. For the benefit of those who are unfamiliar (as was the writer previous to this experience) with the meaning of these terms, it may be explained that the " effective size " of sand as here used is the least size of mesh through which 10 per cent. by weight of the sand will pass, or is in a sense the measure of its

relative fineness or ability to pass the water; and that the "uniformity coefficient" is the ratio existing between the least sizes of mesh which 60 per cent. and 10 per cent. by weight, respectively, of sand will pass. Thus, if 10 per cent. of the sample will just pass a mesh of 0.27 mm. and 60 per cent. just passes a mesh of 0.81 mm., the ratio, or "uniformity coefficient," is 3, and is to a certain extent an indication of the variation in size of grains.

If the effective size is low, — for example, 0.20, — it is an indication of the presence of an excessive amount of fine grains, since 10 per cent. of the whole is fine enough to pass a mesh as small as 0.20 mm. This condition can easily be corrected by washing out some of the fine grains, thus lessening the percentage which will pass a 0.20 mm. mesh and consequently increasing the size of mesh required to just pass 10 per cent.

If the effective size is satisfactory, — say, 0.30, — but the "uniformity coefficient" is too high, — say, 3.50, — it is an indication of an excessive proportion of large grains in the sand, since 40 per cent. of the whole must be larger than 1.05 mm. in the assumed case. This condition may sometimes be corrected by screening the sand through a finer screen, thus removing some of the larger grains and lessening the size of the mesh which still retains 40 per cent. of the sample. When this is done it disturbs the "effective size" by lowering it, and new complications may arise.

To secure from natural sources a large volume of sand possessing the required physical characteristics as outlined above proved in the case of this work a difficult task. The city, acting through its engineers, had, prior to the letting of the contract, caused an investigation of the surrounding country to be made with the idea of locating a possible supply of filter sand. Certain test pits on the city's own property, at a distance of about three quarters of a mile above the location of the work, apparently indicated the existence of a sufficient and satisfactory supply of this material. Laboratory tests of samples from these pits showed the sand to contain an excess of fine grains which could be easily removed by washing. Subsequently, however, when an attempt was made to secure the sand from this locality, it was found to contain only about 1 500 cu. yd. of the 21 000 cu. yd. required, the original indication of quantity proving to have been misleading. No satisfactory material could be found within convenient hauling distance, but a deposit of sand was finally located on private land about one mile below the work, which gave promise of meeting the necessary requirements, provided some

way could be devised to eliminate the excess of coarse grains it contained. Arrangements were made with the owner for securing sand from this property, which was situated at an elevation 100 ft. lower than that of the work, requiring an uphill haul of that amount over the mile of highway separating the two points. The 100-ft. difference in elevation was gained mostly in four separate sharp grades of a few hundred feet each in length. The steam shovel previously mentioned as having been used in excavating for the filters and borrow pit was brought down on its own wheels and by its own power and installed in the new pit for use in loading wagons. Considerable selection of material was required, as the bank varied greatly in its character. When, as was frequently the case, the material in front of the shovel was too coarse for the purpose, it became necessary to mix the loads by adding finer material, loading by hand from some other part of the bank. The run of the bank contained a sufficient amount of gravel to supply the needed proportion of that material for the graded layers previously referred to.

Owing to the excessive grades encountered in hauling to the work, the double teams employed could draw only 1 cu. yd. to a trip. They were assisted up the four steepest grades by tow teams, for which purpose two double teams were permanently stationed at each hill. Ten trips were required in good weather of each team hauling from the pit, and this was reduced to nine and sometimes eight when the roads became heavy from rains. Six dollars per day was paid for each double team, and difficulty was encountered in securing a sufficient number for the purpose at that price. Only the heaviest and strongest teams could stand this haul continuously, and even these lost weight rapidly during the hot weather or when the roads were bad. From 35 to 40 teams were employed at times in addition to the tow teams.

Screening and Washing Plant.

There were required for the purpose of filter materials 17 000 cu. yd. of sand and 3 800 cu. yd. of gravel. One cubic yard of gravel, therefore, was necessary with each 4.5 cu. yd. of sand prepared. Since the material from the pit contained a sufficient proportion of gravel, on the average, to supply the desired amount, the screening and washing plant was designed with a view to obtaining both the filter sand and the required sizes of gravel in one operation.

Delays incident to the securing of a satisfactory source of supply and other causes postponed the starting of this work

until almost the 1st of August. It was imperative that this work should be completed before the cold weather set in, and, therefore, only three months remained in which to prepare and place the 21 000 cu. yd. of material needed. On a basis of seventy working days for the three months, an output of at least 300 cu. yd. per day was necessary to complete the work in time.

A serious feature which caused much apprehension was the scarcity of water available for the purposes of this plant. Previous mention has been made of a brook which formerly flowed over the site of the filters and which was subsequently diverted to a new channel. Though this brook was of considerable size in the spring of the year, it dried up during the summer months to a small flow of about 20 gal. per minute.

It was estimated by Mr. Hazen that 1 000 gal. of water might be required for each cubic yard of sand washed. Consequently if 300 cu. yd. were to be handled in 10 hr., at least 500 gal. of water per minute should be available for the purpose. In addition to the small amount supplied by the brook, there was available a slightly larger amount of water representing the leakage in the 4 500 lin. ft. of tunnel immediately above the work, and in addition the ground water leakage of the filters, which amounted to about 10 gal. per minute. Altogether, therefore, it was possible to obtain a supply of water when utilizing all possible sources of approximately 50 to 60 gal. per minute, or one tenth of the required amount.

On the advice of Mr. Hazen and Mr. Lochridge, all of the water was diverted either by gravity or by pumping into the aërator, which was used as a storage reservoir. Water once used in washing was returned to this reservoir to be used again, and in this manner a sufficient supply was maintained. The returning water brought with it each time the silt and fine sand it had washed out of the materials, which silt was naturally deposited in the bottom of the aërator. When this deposit had accumulated to such an extent as to cause difficulty, the water was drawn down and the sediment removed. It might be supposed that dirty and roily water such as this soon became would add to rather than remove fine particles from the sand. As a matter of fact, however, this sediment carried by the water remained in suspension throughout the operation and was apparently as effective in cleaning the sand as was clean water. Toward the end of the work it became possible to obtain an unlimited supply of clean water from the river supply, which by that time had been diverted through the tunnel. While much

more convenient for the purpose, it cannot be said that it accomplished the result in a more efficient manner than did the dirty water.

The use of the aërator as a storage reservoir for the water influenced the selection of its vicinity as a site upon which to locate the screening and washing plant for preparing the filter materials. Fig. 29 shows the details of construction and final arrangement of the plant, while Fig. 30 shows a view of the plant in operation during the early stages of the work.

The teams drawing from the sand pit entered from the highway and passed across the top of the filter fill on to a bridge which extended out from the filters and over the aërator to the ground beyond. This bridge passed directly over the boots of two 14-in. bucket elevators, located between the filters and the aërator. A hopper under the bridge received the contents of the bottom-dump wagons as they passed over its opening in the floor of the bridge, and the sand and gravel were fed from this hopper on to the bucket elevators by means of two gates at its base. The second elevator was installed as a precaution against possible delays from breakdowns. The sand and gravel were raised by these elevators to a 42-in. revolving cylindrical screen consisting of an 8-ft. section of $\frac{3}{8}$-in. perforation, a 4-ft. section of 1-in. and a 4-ft. section of $2\frac{1}{2}$-in. perforation.

A 6-in. centrifugal pump supplied the water used for washing purposes to the various points where it was needed.

A 35-h.p. steam engine operated the elevators and screen, and the 40-h.p. gasoline engine previously used on the crusher operated the centrifugal pump. Provisions were made which permitted the operation of the entire plant by either engine, and in case of breakdowns this feature proved to be of great value in avoiding delays. The 6-in. pump worked against a total head of about 40 ft., and consumed a large amount of power.

The elevators were often fed at the rate of a load a minute, and during such periods the 42-in. screen was taxed beyond its capacity for handling sand in a dry state. A large portion of the sand was carried over with the gravel and in addition to the loss of this sand the gravel was also spoiled.

In order to assist the action of the screen, a 3-in. connection from the water supply was introduced into the chute through which the material entered the screen, the idea being to bring the sand into the screen in a state of partial suspension and thus to push it through the $\frac{3}{8}$-in. perforations. This method was only partially successful, the water escaping through the first few feet of

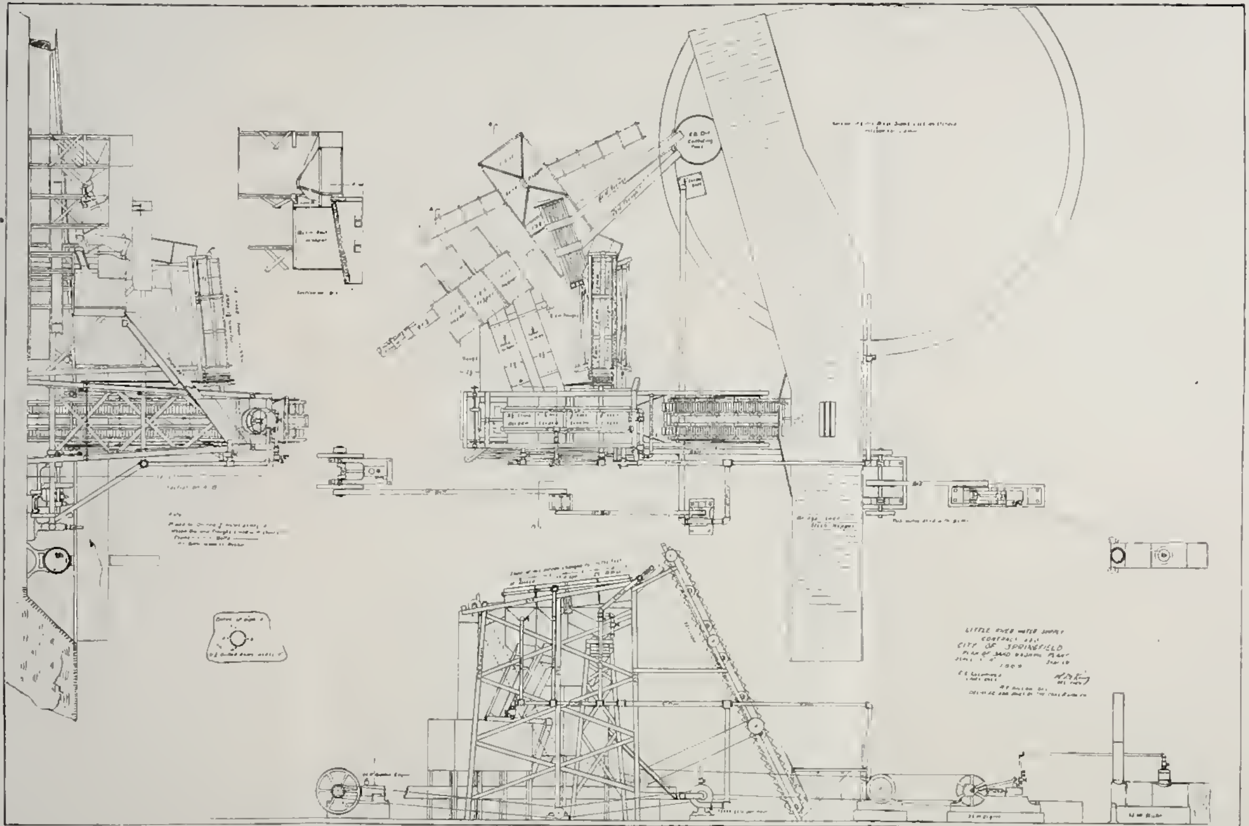


FIG. 29.

screen, while the balance of the fine perforations became clogged with wet sand. To correct this action, one, and later two, 3-in. pipes, perforated with $\frac{1}{4}$-in. holes, were run longitudinally along the top of the screen and adjusted so that the two rows of $\frac{1}{4}$-in. jets played directly downward against the outside of the screen as it revolved. These jets drove back any sand that happened to lodge in the $\frac{3}{8}$-in. openings. In addition, the greater part of the water entered the screen and assisted in flushing the sand out through the bottom of the sand section. It also assisted greatly in cleansing the gravel of sand coatings. So long as a plentiful supply of water under sufficient pressure was maintained in these pipes, good results in separating the materials were obtained. Inside baffle rings between the sections of the screen assisted separation somewhat by retarding the forward motion of the materials. Under each different section of the screen was a wide trough of V-section which collected all of the materials passing that particular section, while a stream of water entering at the end of these troughs through pipes in the lower part of the V caught the material as it fell and carried it forward. The two troughs under the 1-in. and $2\frac{1}{2}$-in. gravel sections pitched at a steep angle toward storage bins. In passing from the collection trough to the bins, however, the gravel passed over a perforated plate which allowed all water and dirt to drop through into a waste trough leading back to the aërator.

The sand, together with all pebbles less than $\frac{3}{8}$-in. diameter, was caught in the trough under the 8-ft. sand section of the screen and carried forward away from the screen by means of the water and a slight pitch given the trough.

The most difficult problem encountered in the operation of this plant was the proper separation of the fine pebbles from the sand needed for filter sand.

While 5 mm., or one fifth of an inch, was the maximum size of grain allowed in the filter sand under the specifications, the admission of all grains up to that size contained in this material would bring the uniformity coefficient considerably above 3, which was the maximum allowance. The general tendency of the material was to run too coarse; and investigation showed the necessity of excluding all grains larger than 2.5 mm., or one tenth of an inch. The grains and pebbles above that size when excluded became available for use in the top $2\frac{1}{2}$ in. of the gravel layer and were, of course, valuable for that purpose.

To effect this separation, the method of passing the stream of mixed water and sand over a stationary sloping screen of the

required mesh was tried with the expectation that the water, together with all sand grains small enough to pass the 2.5 mm. holes, would wash through the screen, leaving the larger grains to pass on to their storage bin. The coarser grains, however, constituted such a large proportion of the whole volume of sand that this method failed absolutely.

A revolving screen 30 in. in diameter and 16 ft. long was then made to order. It was driven by means of an outside band sprocket and contained no inside shaft or arms, but revolved on outside roller wheels bearing against outside track bands. A 3-in. pipe, perforated with a double row of $\frac{1}{4}$-in. holes, passed longitudinally through its center and supplied a constant force of water against its entire inner surface. Wire mesh screen was used, of the required size, and so fastened as to be easily removable to allow renewals. Outside jet pipes were also employed to keep the holes of the mesh open by playing a strong stream against it. The screen accomplished the desired result admirably and gave perfect separation as long as conditions of water pressure, etc., were kept normal. The mechanical construction of the screen proved faulty and it was subsequently replaced with an improved design which gave more satisfactory results from a mechanical standpoint.

Careful and intelligent supervision was required at all times to obtain the best results from this means of separation, and frequent adjustments of the amount of water were necessary with the varying character of the sand supplied. Too complete a separation at this point tended to injure the acceptableness of the resulting sand, by raising its "uniformity coefficient" and sometimes its "effective size," while incomplete separation wasted sand and caused the rejection of the resulting fine pebbles for the purpose of filter gravel.

It is to be noted that these difficulties were due mainly to the necessity of adapting materials naturally unsuited for the purpose to the requirements of the case in hand, and that much simpler and more economical methods would naturally be followed with sand conforming more nearly to the desired quality.

The small pebbles and large grains of sand, rejected by the fine mesh of this screen, passed out through its end and were delivered into an elevated hopper or storage bin.

The sand and water which passed through the mesh of the screen was caught in a trough underneath and discharged into the sand washing box.

This washer was designed by Mr. Hazen, the consulting

engineer for the work. It is of a pattern which has been commonly employed by him in the past and has become more or less familiar to the engineering profession. It consists of a simple wooden box rectangular in plan, 13 ft. long and 3 ft. wide. The top of the box is open and level, while the bottom pitches 2 ft. in its length, the depth of the box being 2 ft. at the shallow or entering end and 4 ft. at the deep or delivery end. Three overflow troughs set transversely of the box with the tops of their side boards just below the level of the top of the box received and disposed of the excess water after the box was once filled. A 5-in. header pipe fed by the water system supplied water to five 2½-in. perforated pipes laid longitudinally in the bottom of the box. A shear gate was provided in the lower part of the delivery end of the box for the purpose of drawing off the sand from the box after it had been washed.

The water and sand from the fine separating screen flowed into the washer at the shallow end of the box. Water from the 2½-in. jet pipes in the bottom maintained this sand in a semi-fluid state and in this condition the contents readily leveled itself through the length of the box. The violence of the jet action produced a continual agitation of the sand and the water, passing up through it, took into suspension and carried upward the sediment and fine grains which it contained. A valve on the header pipe controlled the pressure, and by its adjustment varying degrees of agitation could be produced in the sand. The jet water, carrying with it the silt and fine sand it had accumulated after passing up through the sand mass, was caught in the overflow troughs and conducted back to the aërator reservoir.

The contents of the box, being in a semi-fluid state, could be easily drawn off by operating the shear gate at its delivery end. The sand flowed out through this gate in a steady stream, which, under ordinary conditions was 90 per cent. sand and 10 per cent. water, and discharged into a hopper or small storage bin. It was possible by intelligent control to adjust the gate so that a continuous outflow was maintained corresponding in amount with the incoming sand from the screen.

Frequent samples of the washed sand were tested in the laboratory, and the result of these tests determined the acceptance or rejection of the product. The operators soon became familiar with the appearance of the several grades of sand and made necessary adjustments of water or gates to correct any troubles which manifested themselves.

The output of the plant seldom reached its expected capacity

of 300 cu. yd. in 10 hr. It is probable that this output could have been averaged easily had it been always possible to keep a steady supply of teams feeding the elevators and had delays from breakdowns been eliminated. The bunching of teams on the road in the case of long hauls is inevitable, due to the varying speeds at which different teams walk, and in this case proved an obstacle in the way of obtaining a steady supply at the washing plant. It was possible under favorable conditions to feed a load per minute through the plant, but when ten or twelve teams arrived simultaneously they had either to be delayed for from one to ten minutes or allowed to dump their loads on a spoil pile on top of the filter roof and return to the pit. It would, of course, have been economy to hold them even ten minutes rather than rehandle their loads, but the scarcity of teams and the absolute necessity of obtaining a maximum number of trips from each team working caused the adoption of the latter method. For each such bunching of teams there was a corresponding period during which no teams arrived and during this interval the plant ran empty. Another frequent source of delay was the breaking of some part of the mechanical apparatus, and while repairs were in progress all teams arriving dumped their loads on the spoil piles. As a result of this situation, a night shift was organized to dispose of the spoil pile which accumulated during the daytime, the material being rehandled with wheel scrapers. The maximum output attained in any 10-hr. shift was 320 cu. yd. of sand and gravel screened and washed, but the average was only 160 cu. yd. Had it been possible to keep the plant supplied and running continuously, there is little doubt that under favorable conditions at least 50 cu. yd. per hour of filter materials could have been produced. It is extremely unlikely that any such complicated plant as this, working under similar conditions, can be kept at work continuously. The main mechanical troubles came from the combination of grit and water which was kept out of the many bearings with the greatest of difficulty and which caused excessive wear and breakage on all portions of the plant with which it came in contact. The fine mesh screening wore out rapidly and required frequent replacing. On the second screen supplied, provision was made for the quick detaching and replacing of this fine wire mesh in small sections and it reduced delays of that nature materially.

Fig. 31. Method of Placing Filter Gravel.

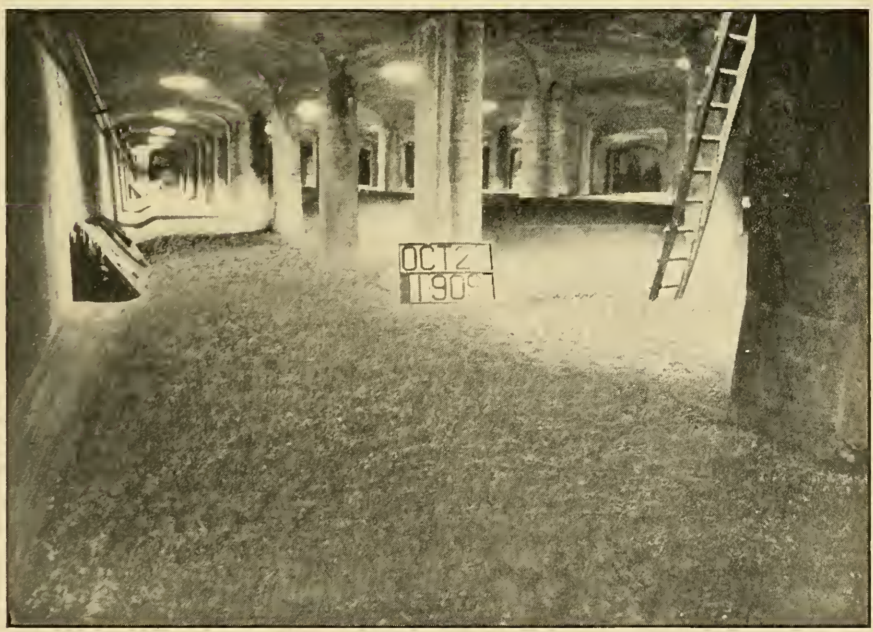


Fig. 32. Method of Placing Filter Sand.

Fig. 33. View of Completed Works.

Placing the Filter Materials.

In placing the filter materials use was made of the manholes in the filter roof which were provided for this purpose. These manholes were arranged in parallel rows 13 ft. apart, the manholes being 26 ft. on centers in each row and staggered with respect to each adjacent row.

The various grades of gravel were deposited separately, at least one row of manholes separating the edges of two successive layers. The bottom or coarse layer was carefully placed around the 10-in. split tile lateral collecting drains, the open joints of the latter being protected by clusters of large stones placed by hand. When sufficient advance had been made with the placing of this layer, the $2\frac{1}{2}$ in. of 1-in. to $\frac{3}{8}$-in. size was started; and it was followed in a similar manner by the fine or "buck-shot" pebbles. Each layer was carefully spread and brought to an accurate grade by the use of rakes. Fig. 31 illustrates the method of placing the gravel.

All gravel was teamed in double or single carts and dumped directly through the manholes to the floor below. The average haul from the washer to the dumping point was about 500 ft.

When the placing of the three layers of gravel had proceeded for a short distance, the depositing of the filter sand was begun. The specifications required that it should be placed in three different layers, each approximately one foot in thickness. It was also provided that the sand should not be allowed to drop from a height on account of the danger of packing. Consequently wooden chutes were used, suspended from a bar across the top of the manholes. By turning the bar the chutes could be made to discharge the sand in a circle surrounding the manhole opening. These chutes had to be made especially strong to receive the impact of the loads of wet sand which were dumped upon them. The sand in the two lower layers was spread by hand to an approximate level and the top layer was graded accurately to the required elevation. Fig. 32 illustrates the method of placing the sand.

The sand was at first hauled in cars or bottom-dump wagons, but, on account of its comparative fineness and the amount of water it contained, great difficulty was experienced in preventing leakage of streams of sand through the small openings and cracks. This not only wasted a large quantity of sand, but the water made the roadways over which the teams had to travel impassable with mud. A system of Koppel cars and portable

track was, therefore, introduced, the cars being of 1 cu. yd. capacity each, while the track extended from under the sand hopper at the washer, over the filter roof to the row of manholes being filled. This track was thrown from one row of manholes to another as the filling progressed. On account of a steep grade from the washer location to the roof of the filters and a few sharp curves in the track, it was necessary to employ a single horse on each car. Three cars were employed in placing the sand and at times carts were used for short intervals to help out.

There was a total of 19 938 loads hauled from the different pits, each containing approximately 1 cu. yd. bank measure. This gives an average of 1.046 cu. yd. of filter materials per cu. yd. hauled. The separation of the gravel and sand naturally increased the total volume, while the washing action removed a substantial amount of sand.

The contract distinguished between filter gravel and filter sand and a separate price was paid for each, but as the two products were obtained in one operation it was impossible to divide the costs between them. Accordingly the following figure shows the average cost for each cubic yard of sand or gravel secured, hauled to the work, screened, washed, delivered in the filter and placed in accordance with the specifications.

Cost of Filter Sand or Gravel in Place.

20 860 cu. yd.

	Per Cubic Yard.	
Expense at Pit.		
Cost of labor	$0.2972	
Cost of fuel, oil, etc	0.0167	
Total cost of teams at pit		$0.3139
Moving shovel from filter to pit and finally from pit to cars at Westfield		0.0163
Teaming from Pit to Work.		
Cost of teams hauling	$0.6345	
Cost of tow teams on hills	0.1373	
Total cost of teaming to work		0.7718
Total cost delivered at work		$1.102
Screening and Washing.		
Cost of labor	$0.138	
Cost of fuel, oil, etc	0.0874	
Total cost of screening and washing		0.2254
Placing in Filters.		
Cost of teaming from washer	$0.1077	
Cost of labor	0.1425	
Total cost of placing		0.2502
Carried forward		$1.5776

		Per Cubic Yard.
Brought forward		$1.5776
Plant.		
Cost of labor erecting and repairing	$0.0932	
Cost of materials used	0.1322	
Total cost of erecting and repairing	$0.2254	
Removing Plant.		
Cost of labor	0.0184	
Total cost of plant per cu. yd		0.2438
General expense, 12.9 per cent		0.2347
Grand total cost of this item		$2.06

Comment on above figures: The item of labor and teams loading includes the expense of the following items of work:

Labor and teams building roads to and stripping (2 ft. deep) site of first pit.

Loading all teams by hand at first pit.

Labor sinking several test pits in various localities while searching for new supply.

Labor and teams stripping (2 ft. deep) second pit and building roads.

Labor on and around steam shovel used in loading.

Labor loading by hand in mixing fine material with coarser loads.

Labor and teams rehandling material dumped in spoil pile on filter roof and utilized by the night shift on the washer.

It will be seen, therefore, that this figure of approximately $0.31 per cu. yd. is made up of so many different items of work as to have little significance as a guide for future work. The labor cost of operating the shovel was $10 per day, which for an average of 160 cu. yd. per day would be equivalent to $0.63 per cu. yd. There will naturally be some stripping in all cases, and usually some incidental expense outside the mere cost of loading. A high-priced foreman was deemed necessary in this case to direct the selection of material and to regulate and supervise the teaming work. This item alone added $0.031 per cu. yd. to the cost of loading. All of these expenses would be reduced proportionately by an increased output per day.

The figures for teaming show the effect of the cost of tow teams. These same tow teams could have handled some additional teams at times, although for the most part they were kept busy. One hundred and seventy tows per day was about the limit for one team on these hills.

The unit cost for screening and washing would be cut down with an increased output since the total is fixed.

The cost of teaming from washer to filters includes also the cost of disposing of much surplus gravel, mostly tailings or stones over $2\frac{1}{2}$ in. and some of the fine or "buck-shot" grade. This item of expense also covers the cost of cleaning up and regrading the surface of the filter roof fill on the completion of the work.

The cost of plant is very heavy since it includes the cost of experimenting and remodeling as well as a large amount of renewal and repair work.

It is probable that the use of a series of inclined stationary bar screens or gratings for the removal of the tailings, $2\frac{1}{2}$-in. and 1-in. gravel, would have been more satisfactory and economical than the use of the 42-in. revolving screen. The repairs and alterations on this screen formed a large portion of the plant repairs charged.

The contract price paid for filter gravel was, per cu. yd.,	$1.25
The maximum price bid was, per cu. yd.	2.10
The minimum price bid was, per cu. yd.	1.25
The average price bid was, per cu. yd.	1.545
The contract price paid for filter sand was, per cu. yd.,	$1.00
The maximum price bid was, per cu. yd.	2.00
The minimum price bid was, per cu. yd.	1.00
The average price bid was, per cu. yd.	1.555

The above prices were bid and based upon the assumption that sufficient material suitable for the purpose would be obtained at the site of the first pit, giving a short, downhill haul to the work and of such character as to offer no special difficulties in separating or washing.

Split Tile Drains.

These drains were laid on the floor of the filters at right angles to the 24-in. central outlet drains which ran longitudinally under the center of each filter and connected with them by means of 10-in. tees turned up through the floor every 13 ft. The split tile was of 10-in. diameter, laid with open side down and with open joints. Each transverse row was located in a valley of the floor, the rows being 13 ft. apart and passing over the upturned 10-in. tees from the central drains.

The split pipe was hauled from the railroad, unloaded and distributed in the filters by lowering through the roof manholes, and was laid just in advance of the gravel layer.

Large stones were selected from the coarser gravel layer and placed by hand around the open joints of the split pipe in order to prevent smaller stones from entering through them.

The cost of drains was as follows:

COST OF 10-IN. SPLIT TILE DRAINS.

9 360 lin. ft.

Cost of pipe and freight	$0.118	per lin. ft.
Cost of teaming to job	0.015	per lin. ft.
Cost of labor unloading and laying	0.006	per lin. ft.
General expense, 12.9 per cent	0.018	
Grand total cost of this item	$0.157	per lin. ft.

The contract price paid for this item was, per lin. ft.	$0.267
The maximum price bid was, per lin. ft.	0.48
The minimum price bid was, per lin. ft.	0.176
The average price bid was, per lin. ft.	0.273

CAST-IRON PIPE.

In connection with the distribution of the water to and from the filters and other structures, about 318 tons of cast-iron pipe were used, ranging in size from 6 in. to 36 in. in diameter. From the nature of the work much cutting and fitting was necessary, and a large part of the work consisted in the setting and fitting of specials and gates. It was in general necessary to lay this pipe in small sections as the work progressed, and this feature added greatly to its cost. Several tons in the basement of the office and laboratory building were laid with flanged joints, but the greater portion of the pipe was of the bell-and-spigot type, laid with lead joints.

The pipe was furnished by the city, and delivered on cars at Westfield.

It was possible to handle a small portion with the derricks used in concreting, but the greater part was handled and placed by hand and with ordinary trench derricks.

The cost of the cast-iron pipe work was as follows:

COST OF LAYING CAST-IRON PIPE.

317.6 tons.

Cost of labor unloading from cars at Westfield,	$0.60 per ton	
Cost of teaming to work	2.10	
Total cost on job		$2.70 per ton
Cost of labor in handling and laying	$3.46 per ton	
Cost of teams used in laying	0.35	
Cost of miscellaneous supplies	0.02	
Total cost of laying		3.83 per ton
Carried forward		$6.53 per ton

Brought forward		$6.53 per ton
Cost of labor calking	$0.83 per ton	
Cost of lead, etc., on job	1.46 per ton	
Cost of jute	0.08 per ton	
Total cost of making joints		$2.37 per ton
General expense, 12.9 per cent		1.19
Grand total cost of this item		$10.09 per ton

The contract price paid for this item was	$12.00
The maximum price bid was	30.00
The minimum price bid was	6.50
The average price bid was	13.17

Cost of Keeping Horses.

During the first season's work, all teaming and horse work except that used in hauling from Westfield was done by teams either owned by the company or hired and kept by it. The maximum number of horses owned was 43, and the maximum number hired and kept was 10. The hired horses were paid for at the rate of $1.00 per day per horse. Of the horses owned, five were lost from one cause or another.

A stable was constructed 100 ft. long by 30 ft. wide, and accommodations were provided for the above number of horses.

Twenty "Troy" bottom-dump wagons were purchased, in addition to six wheel-scrapers, caravans, express wagons, etc.

The work was unusually severe on the horses on account of the uphill hauls. All the horses were young, green horses when purchased and cost an average of $230 each. They were acclimated without any serious trouble by giving them light work for the first few weeks.

On completion of the first season's work all of these horses were sold rather than undergo the expense of keeping them over the winter months, and during the second season's work all teams were hired and paid for by the day. The figures here given apply only to the first season and are reduced to cost per horse-hour actually worked. There were usually some horses unable to work due to sickness or other causes, and more or less lost time on rainy days and Sundays, so that a better idea of cost can be obtained from the unit selected, viz., the horse-hour actually worked.

The cost of owning and keeping these horses, including all expenses connected with the teaming operations, was as follows:

COST OF TEAMING WORK.

72 474 horse-hours.

Buildings.		Per Horse-Hour.
Cost of materials used in building stable..............	$0.006	
Cost of labor on same..............................	0.0033	
Cost of proportion of materials used in blacksmith shop..	0.0001	
Cost of labor on same..............................	0.0010	
Total cost of buildings..................................		$0.0104
Depreciation and Repairs.		
Cost of depreciation on horses including freight......	$0.041	
Cost of depreciation on harnesses and repairs on same,	0.01	
Cost of depreciation on wagons and repair parts for same,	0.01	
Cost of labor on wagon repairs	0.0036	
Total cost of depreciation and repairs		0.0646
Cost of insurance		0.006
Cost of rent paid for hired horses		0.02
Cost of teamsters and barn men..........................		0.1137
Cost of labor shoeing..........................	$0.0055	
Cost of materials, shoeing......................	0.002	0.0075
Cost of fodder of all kinds		0.0845
Grand total cost of keeping horses per horse-hour actually used,		$0.3067

Cost of single teams per hour..............	$0.39
Cost of double teams per hour.............	0.605

Comment on above figures: The entire cost of the stable and a fair proportion of the cost of the blacksmith shop is charged against this one season's work. Had the horses been kept for the two seasons, the figure would be reduced one half.

The depreciation on the horses represents the value of five horses lost and the shrinkage in value of the remainder after one season's work. This figure would also probably show some improvement if extended through two or more seasons.

The wagons received rather severe usage under the steam shovel, and repair bills were correspondingly large.

The rent paid for hired horses was high, being $1.00 per day per horse in addition to their care and feed. The total amount so paid was $1 386, but considering the depreciation suffered by these horses due to the severe nature of the work required of them, it cannot be called excessive.

The cost of transporting the hay and grain added considerably to the cost of feeding, and the amount fed to each horse

averaged higher than would be the case for horses doing lighter work.

During the second season's work all teams were hired outright for $5.50 per day until the middle of the season, when teams becoming scarce, the rate was raised to $6.00.

Buildings.

Office and Laboratory Building. — This building is of reinforced concrete throughout except the roof which is of wood frame covered with red tile. It is 47 ft. by 27 ft. in plan, two stories in height with a pitched roof. The floors are of reinforced concrete. On the lower floor is a power room 25 ft. by 17 ft. containing a water turbine operated by the water flowing from the basin to the aërator. This turbine drives a 6-in. centrifugal pump for furnishing water pressure to all parts of the plant, and a dynamo for furnishing electricity for lighting purposes. A second similar room on the lower floor is provided with necessary apparatus for chemically treating the water should it be necessary. The second story contains a large store room and a laboratory. The building is heated by hot water and equipped with a modern plumbing system, including a complete bath-room.

The actual cost of the building complete above the foundation, including plumbing and heating, but exclusive of hydraulic or electric machinery was	$9 435
The contract price was	11 000
The maximum sum bid was	15 000
The minimum sum bid was	5 400
The average sum bid was	9 386

Reduced to price per cu. ft., the above figures become 31 cents, 37 cents, 18 cents and 31 cents respectively.

Regulator House. — This building is 35 ft. by 35 ft. in plan, of reinforced concrete, one story high, and is covered with a flat gravel roof. Its interior is plastered. The floor is of concrete, but covered only 33 per cent. of the area, the remaining space being occupied by open wells. In this building are the controlling valves on pipes from the filters and all recording apparatus of the Venturi meters.

The actual cost of this building was	$3 838
The contract price paid for this building above the foundation was	4 200
The maximum price bid was	6 500
The minimum price bid was	2 000
The average price bid was	3 658

Reduced to price per cu. ft., the above figures become 26 cents, 28 cents, 43 cents, 13 cents and 24 cents respectively.

Filter Entrances. — For the purpose of entering the seveial filters, entrances and stairways were provided over the first, third and fifth division walls, each building admitting to two filters. These buildings are of reinforced concrete 13 ft. by 13 ft. in plan and covered with pointed, tile roofs. They are plastered on the inside.

The actual cost of these buildings was, each..........	$910
The contract price paid for these entrances, was, each..	1 000
The maximum price bid was, each..................	2 000
The minimum price bid was, each...................	425
The average price bid was, each....................	943

Reduced to cost per cu. ft., these prices become 46 cents, 50 cents, $1.00, 21 cents and 47 cents respectively.

Other Items.

The remaining eleven items of the contract were of a miscellaneous character, and description of the methods or costs as far as they are concerned would probably be uninteresting and uninstructive.

Conclusion.

In the foregoing description an attempt has been made to state clearly the conditions under which the several costs were contracted. There remain, however, some general statements, a knowledge of which is necessary if the figures given are to be used and applied intelligently.

Labor Conditions. — During the first season's work common labor of satisfactory quality was easily obtainable and was paid for a short time at the rate of 15 cents per hour. A limited number were, however, allowed 17.5 cents and mechanics were paid the customary rates pertaining to their trades, i. e., hoisting engineers, $3.50 to $4.00 per day; carpenters, $3.00 to $4.00 per day; blacksmith, $3.00 per day; teamsters, $1.75 per day. Foremen received $30 per week in addition to their board. After the first few months of work the rates of common labor were increased to 17.5 cents per hour and those especially capable were paid 20 cents.

During the second season the rate of 17.5 cents was maintained for the early half, but the supply of good labor then becoming scarce the rate was later increased to 20 cents and that for picked laborers to 22.5 cents and 25 cents per hour.

Weather Conditions. — The weather conditions were exceptionally favorable throughout the period covering the work. Both seasons were far below the average in matter of rainfall, and the small amount of precipitation recorded occurred usually in a few large storms rather than in many small ones. A large percentage of the rains occurred at night or on Sundays, and the total lost time due to weather conditions did not exceed ten days for the two seasons' work.

Character of Engineering and Inspecting. — An important feature to be considered in connection with the analysis of cost data is the character of the engineering and inspecting under which the costs were contracted. It is no exaggeration to say that contract costs on public works may easily vary as much as 10 per cent. with the varying degrees of compliance exacted by engineers and inspectors charged with the enforcement of contracts and specifications.

On this work a most liberal spirit was manifested at all times by the entire engineering force in interpreting and applying the specifications. In fact, the coöperation, advice and assistance of the engineers and of the water board were available to the contractor at all times, and were freely used by him to his great advantage. The specifications and contract were rather more liberal and equitable in tone than is customary in similar cases, and in addition great latitude was permitted the contractor in carrying out their provisions. Frequent modifications of specified requirements were made from time to time in favor of the contractor when such changes did not in the engineer's opinion affect the ultimate quality of the work. It will be readily appreciated that costs contracted under these conditions will be much less than would be the case if similar work were done under exacting and arbitrary engineering supervision.

General. It may be charged with some reason that certain of the cost figures are so high as to indicate mismanagement or gross inefficiency on the part of those in charge. It should be borne in mind, however, that bad management is as much a contingency to be expected and provided for as is bad weather or bad ground. The available supply of competent foremen, laborers and mechanics is not sufficient to insure always the obtaining of a satisfactory and well-balanced organization after

the contract has been signed; and in contracts involving, as did this one, a great variety in classes of work, it is not to be expected that equal proficiency can be attained in handling the several different kinds of work involved.

DISCUSSION.

Mr. Elbert E. Lochridge. — I will not enter into any extended discussion of Mr. Gow's paper. I think it is always a good thing to bring before engineers the real figures of any contract with which we are familiar. That is, as we make up an estimate for work which is to be done, we take into consideration all of the features that we can get hold of; in other words, we put in our test-pits, we show the contractors what can be done in the way of material, of location, and the general facilities for the work. If we have a number of contracts running at the same time we find how the different contractors take hold of them. One man is especially efficient in handling his concrete, another man is especially efficient in handling earth, and the various features are specialized by the different men. In this work and in these comparisons which Mr. Gow has made in his paper, he has gone into the costs and compared them with the bids, — the highest and the lowest bids, — his bid price and what it cost him to do it, and as you will see in some of these cases there is a great variation.

To enter into a few of the difficulties that the contractor has to meet on such a job, I will take up this particular contract. We went over the ground and put in test-pits at various points to determine the quality of the material which he was to excavate. We also went into the sand banks which were developed above, made an analysis of them and found we had satisfactory filter sand, or sand which could be made satisfactory by washing. In both of these cases we handed Mr. Gow a gold brick, because we put our pits down into large sand banks which tested very good, but which ran out, that is, sand of quality shown by our pits was very limited in amount. In our filter-site test-pits — I have forgotten the number, but they covered pretty generally the area which was to be excavated, 17 feet deep at one end and running out to nothing at the other — we carefully avoided running into any bowlders. I don't know whether we had a divining rod or how we missed them, but at any rate these pits formed the basis for his prices. These facts merely illustrate the gamble which any contractor takes in undertaking any big job.

In this particular case, as Mr. Gow has described to you, he put in a steam shovel which was supposed to do that class of work, and found he could bend the arm or tear off the teeth without taking up very much of a load. And this, I think, proves very clearly to us some of the responsibilities which we as engineers have in laying out work and giving to the contractor the fullest and most accurate details that we can. I think that contracting at best is a gamble, in the bringing in, as it does, of various conditions of weather and of material and of labor conditions, etc. It is for this reason a duty of the engineer to place all the facts as clearly before all of the bidders as can possibly be done.

To go a little further into some of the costs and some of the discrepancies with the bid of Mr. Gow, — which, of course, was largely based on his past experience, and shows the variation in the cost of these materials from what his experience or investigation would bring out, — we find the very variations which are interesting to us as engineers are helpful in making up estimates for future work.

The question of the location which Mr. Gow touches on comes in. Here he had a haul of six miles from the nearest railroad — some of the contractors on this work had a good deal more, but here he had a haul of six miles — at a time when it was almost impossible to secure teams, which ran up the costs very largely, and you find in connection with his excavation that this, also, was of considerable importance.

Taking up the question of concrete. Filter construction is a little different from general concrete construction. The floors, pillars and the vaulted roof make three distinct types, and I believe in this particular case different prices were bid upon them. A contractor in going into this work, having only had experience with other classes of concrete construction, must to a considerable extent guess on the work. Here I will throw in just another feature which is not new to most of you, and that is, after the engineer makes his estimate and knows something of what that work is to be, he should go over the bid very carefully to see whether the contractor has bid enough to do the work, because I believe it is very poor economy to let the low man have the job simply because he is low. On this general work we had two experiences of this kind, and let one contract, I think, $30 000 above the lowest bidder; and in that case we had the work well done.

I will say for Mr. Gow that he took up a very difficult job, and one which was very discouraging for a long time, in a way that won for him the admiration of the water commissioners and

the engineers with whom he worked. He did without any hesitancy on his part everything that the contract called for. There was no question at all that the contract would be carried out in letter and in spirit, whether he lost or made money. And I don't know that he ever asked to get out of anything because of these items he has shown you, wherein the money coming in was not as great as the cost.

I will bring up just one more difficulty Mr. Gow had, and that was the one of filter sand. Mr. Gow had rather hard luck in securing a satisfactory filter sand. I don't like to have these papers go into the records of the society in such a way that all contractors are going to say, "There is Mr. Gow. He couldn't do it for less than so many dollars a yard, and that is the best that can be done." That undoubtedly was as good as could be done in this case. But conditions might be much more favorable. In fact, here a long uphill haul was necessary and we found that conditions as laid out were so manifestly unfair to Mr. Gow that the board met the point fairly, said that we had not represented the conditions exactly as they were and made suitable allowance for it. I think that, too, is a province of the engineer, where it is possible and where it is right and just, to see that the conditions under which the job must be done are fully considered and balanced at the end of the work just as fully as they are at the beginning.

Mr. Allen Hazen (*by letter*). — I have read Mr. Gow's paper with the greatest interest. Data of the kind which he gives are those which enable an engineer to get a true basis for estimating work in other cases, and for forming a judgment as to the reasonableness of bids and contract prices. Too often the best data that are available for this purpose are of a very indefinite character, and though they may be useful even though indefinite, they are not as satisfactory as the actual figures which Mr. Gow has given us for this particular job.

The thoroughness with which the work is done is often an element in the whole cost of the work, and I do not find that Mr. Gow has mentioned this phase of the subject. As a statement concerning it seems essential to round out the paper, I am glad to say a word. Mr. Gow's work was uniformly well done, in accordance with the intention and spirit of the specifications. I think that it was because the engineers appreciated this condition as the work went forward that they were sometimes willing to make the slight and relatively unimportant changes in the specifications that Mr. Gow has noted in his paper, which facilitated

his work without detriment to the city's interest. Certainly an engineer can do this much more readily and with greater propriety where the work is going forward rapidly and well than where the work is behind or of unsatisfactory quality.

There was a particularly interesting question in this case as to the interpretation of the contract, namely, in regard to getting the filter sand. Long before the contract was let, the engineers had opened test pits in the neighborhood of the work, and on a side hill above it, in the effort to find a supply of stock which could be used for the preparation of filter sand. The men who dug the test pits soon learned what kind of material was wanted and were clever in finding it. Test pits were opened that disclosed material of the right grade, and enough to justify the hope that the whole quantity of filter sand could be obtained. The location was near the work and above it in elevation, so that it would be a continuous down-hill haul to the filters.

When the bank was opened up, the test pits proved to have been sunk in relatively small pockets of good material and the bulk of the stock could not be used.

Further investigations disclosed a supply of material that was suitable, and this was used. The new deposit, however, was farther from the filters and below them, involving a hard up-hill haul, and much added cost to the contractor.

Under these conditions we asked ourselves who was responsible for this added cost? The contractor had signed a contract under which he had assumed the risks. On the other hand, he had been shown the test pits of favorable material above the work, and had been told that the engineers believed that the filtering material could be secured from that location. All our contracts are drawn upon the theory that the contractor assumes responsibility for unexpected conditions, and this seems to be necessary. If it were not so, the engineer would constantly face claims for added compensation because of alleged changes in conditions, many of which did not exist. But here was a case that was out of the ordinary. The engineers as well as the contractor had been misled by test pits, and conditions were found to be widely different from those which were supposed by the contracting parties to exist when the contract was made.

It seemed under the circumstances that it was fair to hold that the city had in effect guaranteed the sand deposits, and that it was equitable for the city to make the contractor good for the additional expense reasonably involved in the additional haul. This is a point on which discussion may be especially helpful.

The effect of the extra haul in this case was to largely increase, in fact nearly double, the cost to the contractor of securing the filter sand. The methods of separating, washing and handling filter sand have been greatly improved in the past years, so that while the quality of sand reasonably required is very much better than was required in some of the earlier sand filters that were built, the cost of securing it has frequently been very moderate. In other contracts for sand filters the item for filter sand has frequently been a profitable one to contractors, and in one notable instance it was very much the most profitable item in a large piece of work.

Mr. Gow's bid in this case was lower than the engineers expected; but if the deposit above the works had come up to the indications of the test pits, I do not think that he would have lost much money, even under his low price.

In contracts of this type the engineer acts as arbitrator between the contractor and owner. He is bound to do even-handed justice to both parties. It is just as wrong for him to underestimate the contractor's work, to refuse to allow reasonable extras, or make decisions that hamper the contractor or obstruct his work unnecessarily, as it is for him to overestimate the contractor's work or favor the contractor in any way at the expense of the city. In other words, the contractor's interest must be protected by the engineer just as carefully as the city's interest.

In this case it is a pleasure to note that the engineers' efforts to carry out their plain duty under the contract were appreciated by the contractor.

The Chairman. — I should like to ask Mr. Gow if his experience with the automobile dump cart will give him any line as to the probability of automobile gravel hauling displacing horse gravel hauling.

Mr. Charles R. Gow. — I suppose that would depend a good deal on conditions. In hauling from the ordinary gravel pit, it might be necessary, with an automobile truck built to carry heavy loads, to construct something more substantial in the way of a road than would be the case with a team of horses. Of course, in our case we hauled from a hopper which was loaded by elevated cars running from the pit, and the hopper was situated by the side of the road. So that particular difficulty did not occur. But in long hauls I should say that undoubtedly the automobile truck would pay, not only in hauling sand and gravel, but in the hauling of any material. In the shorter hauls, I have some doubt as to its relative efficiency. The value of the auto-

mobile truck lies in the fact that it can cover long distances in a short time, and we found that particularly advantageous in this case. The paper mentions the fact that late in the season, about this time of the year, we commenced to experience difficulty with the automobile truck in that country. The grades, as you may imagine from the varied descriptions in the paper, were very steep, and the roadbed was of the type usually found in country districts where no attempt has been made at surfacing. At this season of the year the ground froze at night to a depth of two or three inches or more, and remained so until the middle of the forenoon, when it started to thaw. As soon as the thawing action commenced, a film of mud formed on top of the frost, so that on the grades the truck was practically uncontrollable; and it became so dangerous, and there were so many narrow escapes from capsizing the truck, that it was considered advisable to withdraw it. That was so even with chains. We had difficulty on some of the steeper grades in keeping the truck from sliding bodily. Outside of that feature, there is no question in my mind that automobile trucks would be serviceable, as a general thing, for all long hauls.

Mr. James W. Rollins (*by letter*). — The Society is to be congratulated upon having been given this most finished and excellent paper by Mr. Gow. The writer has never seen any article clearly stating costs and the division of same so completely; and as such it should be of great interest and use to the members of this Society. Often we see papers or statements of engineers as to costs, but they never can know of the expenses of doing the work, and can judge only by the labor cost, actual cost of material used, and a guess at depreciation. Few of them would admit, and most of them do not even know, of the item of *general expense*, which Mr. Gow figures absolutely and accurately at $12\frac{1}{2}$ per cent. of the whole contract.

Cost data should be used only as a guide, a record of experience, and if one has had a good lot of such, they can be used in figuring work, where the conditions of work to be done correspond in some measure with that which has been done; but this agreement of conditions must exist to make safe the use of cost data; otherwise it comes to a matter of judgment as to the value of work to be done; and in the opinion of the writer this judgment is one that certain men are "born to," and is not always acquired by experience. This accounts, in a measure, for the truthfulness of the saying, that "engineers do not make good contractors"; the reason is that engineers trust too much to

their figures, to the small details of work, and have not that inborn judgment of what a certain class of work is worth, and general broad knowledge of the vital conditions to take up, letting the small ones go by.

Referring to Gillette *cost* data on pile-driving, for an example he quotes one job where 50-ft. piles driven in soft clay cost 70 cents each for labor to drive. Another lot of 51-ft. piles cost $1.75 each. Another lot driven 14 ft. into ground cost only $1.54 each. Another lot 37 ft. long — and a large number, 3 638 — cost $2.26 each.

From our own records, we drove 230 piles in a day, at a cost of $25, or about 8 cents per pile. Another job shows 3 piles driven in a day at a cost of $20, or $6.33 each.

The above data cover a lot of work and different conditions, but we seldom know the pile-driving conditions in advance of the work; and in the writer's opinion none of the above cost data could be used properly in estimating work, as an average even would not give a suitable figure.

Pile-driving is, however, perhaps one of the most uncertain classes of work that is done, but the application of *cost data* to this and similar classes of work must, in the opinion of the writer, be made with great caution and judgment.

Cofferdam construction, driving of sheet-piling, is even more uncertain than pile-driving, and even the estimates of the most experienced engineers may be wide of the mark.

The item of *general expense* is to-day a "sticker," and the writer knows that figures are not made high enough for this item, which seems to increase far faster than the "high cost of living." Machinery is so much used to-day in all large work that its installation, maintenance and depreciation carry this general expense item high in cost. Insurance is another factor of this cost, as to-day no contractor dares go ahead with his work unprotected. The increased cost of labor and the short hours worked also increase the percentage of the general expense account.

On our payroll accounts alone the item of general force is from 6 per cent. to 18 per cent. of entire payrolls. This general force is superintendent, watchman, timekeeper, blacksmith, material clerk and certain other small items. Recent contracts show this as follows.

Contract.	Amt. of Payroll.	Gen'l Force.	Per Cent.
Charles River Dam	$226 960	$41 190	18
Fall River Bridge	102 178	10 701	10
Saybrook Bridge	48 768	6 147	12.7
Buzzard's Bay (Bourne)	18 604	1 072	6
Charles River Embankment	70 663	6 157	8.8

The Charles River Dam was spread over five years' time, in a part of which time little work was done, but the executive and general force was maintained.

Charles River Embankment had no superintendent, as this work was done in part by the superintendent at Charles River Dam.

Buzzard's Bay was, in part, a pneumatic job, which brought the labor up, so decreasing the percentage of general force.

The figures on Charles River Dam also show most plainly the loss on a long-time job where the work is not pushed; as does Buzzard's Bay show the contrary, i. e., the small percentage of general force on a job that is pushed.

In addition to this general force account is the "bill item" or "general expense" on a contract. This includes coal, water, freight on plant, small tools, insurance, rope, rigging, etc.

Contract.	Total Cost.*	Bills.	Per Cent.
Fall River Bridge	$401 000	$70 100	$17\frac{1}{2}$
Charles River Dam	1 657 000	152 564	9
Saybrook Bridge	128 834	17 268	14
Bourne Bridge	42 504	9 335	22
Buzzard's Bay Bridge	71 757	15 516	21
Providence Bridge	255 811	55 941	22

* Total cost includes payrolls.

Commenting on the above figures, it seems that water jobs are about uniform in 20 per cent. average.

Charles River Dam was a strung-out job in which plant did not probably suffer as much as in the other jobs, which were pushed through in a short time.

From the above figures it will be seen that General Force and General Expense are not myths; and to leave them out of account on Extra Work means that such work is done at a loss — even with the 15 per cent. for profit generally added.

It has been a great satisfaction to the writer to read the clear and straightforward statement of Mr. Hazen regarding the final adjustment of the payments on account of changes in the conditions met with in the work from those as shown by plans and specifications. The old forms of contracts always stated that the "engineer was to be the arbitrator between the parties in interest"; but of late years it has been dropped and the writer at times thinks the spirit has been dropped. Contracts are written with clauses under which the contractor has absolutely no redress for changes of conditions, and is held liable for

all accidents or losses due to negligence even of the owners or their agents; and the old spirit of dealing "man to man" and settling differences in that way apparently is being cast aside. So Mr. Hazen's statement that the commission on this work dealt with the problem in the old way, paying for work done under different conditions from those both engineers and contractors expected, is a most gratifying one in these days when most commissions and engineers "duck" behind responsibility clauses they themselves created in making a contractor responsible for everything.

Again was evident in this work the spirit of helpfulness, good-fellowship and faith, one with the other, between the engineers and the contractor — acknowledgment of good, true work done by the contractor, on the one hand; and of fair treatment and just dealings given by the engineers to him. Do you engineers know how much this means both to the work, its faithfulness and good execution, to have this spirit exist? It permeates every man on the job: the engineers; the contractor's force, from the superintendent to the waterboy; and with every one pulling together, everything, the job itself more than all else, gains.

There is much to be said on the question of day labor versus contract work. The writer's opinion is that most contractors prefer contract work; but that certain classes of work, where great uncertainties exist, should be done by the day; and that all straight work should be done by contract.

It has repeatedly been our experience in day work, especially where material is furnished by the owner, that the rigid inspection given to contract work and material is not adhered to in day work. "Good enough for the place" is the war cry, and not "Follow the terms of your contract."

The writer agrees with Mr. Gow, in part, in his statement that the cost of public work may vary ten per cent., according to the engineer in charge. Some engineers we absolutely "duck" and decline to figure on work they are to have charge of. Others we gradate from fifteen per cent. down, according to our knowledge of their practice in interpreting specifications, and as to whether or not they wish to make a series of laboratory experiments with the job and the contractor's plant. The success of most jobs is made possible or impossible by the engineer, hence the contractors in their bidding group the engineers into classes ranging from those to whom no bids will be submitted, down through those for whom ten per cent. is added, to those for whom

the figure is normal; and I am very thankful to say most of the engineers get into this latter class.

MR. SANFORD E. THOMPSON. — I wish to express my appreciation of the thorough method of presenting costs which has been followed by Mr. Gow so as to give in detail the items of greatest value and the arrangement, divisions and description of them so that they are of good reference value even in cases where the conditions are quite different.

Arrangement of costs is of such importance, and so few writers give the data in a form to be of appreciable value for a job where the conditions are slightly different, that attention may well be called to a few of the essentials in such tabulations.

(1) Costs of most value are those which apply to common work and ordinary conditions rather than to extraordinary ones; the average engineer or contractor, for example, will have to figure the cost of excavating gravel one hundred times to one estimate on frozen clay. (2) Costs should be separated into unit prices to apply to subdivisions of the work; in fact, elementary items, such as the cost of grubbing per stump given by Mr. Gow, are frequently of more value than over-all costs. (3) The units should be selected to eliminate variables as far as possible; for example, general costs of concrete forms in terms of per cubic yard of concrete are valueless because inversely proportional to the thickness of the wall. (4) Supplementary data, such as distances, heights and qualities of material, must be stated or it will be impossible to tell whether the values can be used in new cases; for instance, in hauling gravel, the distance hauled and other details must be stated. (5) The work must be described in sufficient detail to give a full understanding of the local conditions; frequently the weather or labor conditions or politics may appreciably affect the cost. (6) The rates of labor and the unit prices of materials must be stated; these are such obvious requirements that it would seem superfluous to refer to them, yet frequently they *are* omitted entirely. (7) General expenses should be given in detail and properly allowed for in all items in a manner somewhat similar to that followed by Mr. Gow. (8) In making up the costs, ample allowance must be made for depreciation of plant as well as the first cost or interest on the first cost; on some jobs the entire cost of plant must be charged, in others the difference between the value new and after use, while frequently it is most convenient to charge a certain percentage, say twenty-five per cent. a year.

A complete statement of all of these points requires great

care in compiling and arranging the matter for a paper or magazine article, but the results will enhance the value to the reader in an almost immeasurable degree.

The results attained in Mr. Gow's paper are evidence of a good method of cost keeping. In dividing different classes of work the speaker has always found it most convenient to use letters or a combination of letters and figures which will have some meaning in themselves instead of using either the decimal system or an alphabetical system beginning *a*, *b*, *c*, etc. For example, referring to Mr. Gow's tabulation on page 192, *E* might stand for general excavation, *H* for hand excavation and *L* for labor. Then instead of writing 2a′, which has no meaning in itself, the item would be *EHL*, which immediately suggests to the mind *E*xcavation by *H*and *L*abor. By selecting initial letters or letters that are prominent in the word required, and introducing intermediate figures if convenient, it is possible in any kind of work to prepare a system of notation which can be read at a glance. The speaker, for example, has an index on concrete alone with 240 subdivisions, each of which is designated by a combination of two or three letters that can be read at a glance and remembered. The scheme when fully developed is termed the mnemonic system of notation, and has been used effectively in large establishments in distinguishing all the varied operations.

Another portion of Mr. Gow's paper which specially interested me is that referring to the sand used in the concrete. The statement is made that the local sand, "although to all appearances excellent in quality, contains some agent antagonistic to the cement." This is another of the illustrations, constantly occurring, of the absolute necessity of testing sand for concrete which comes from any new bank — or, in fact, which comes from an old bank that has not been actually tested. The fact that a certain sand looks all right and has been used for other concrete is no guaranty that it is suitable for an important structure requiring good strength and uniformity. If the case cited were an isolated one, the conclusion that sand tests are absolutely necessary would not be so inevitable, but similar cases are coming to light in all sections of the country and unfortunately the sand frequently looks so good that the experienced engineer or contractor is totally deceived, and the fault is not discovered until a large mass of concrete has been laid and has failed to harden.

In our neighboring city of Cambridge there are several

localities where the sand makes a concrete or mortar which will hardly set at all. We have come across the same thing in different parts of Massachusetts, in New Hampshire, Connecticut, Rhode Island and other states.

The surest test for a good sand, and one which can be applied in any cement laboratory, is to compare the tensile strength of mortar briquettes made of the sand in question with briquettes made of standard Ottawa sand and the same cement in like proportions. According to the requirements of the Joint Committee, the mortar with the bank sand should have a strength at least seventy per cent. of the standard sand mortar.

The best plan to follow, in case a sand fails to make good mortar, is dependent on the local conditions. We frequently find that good sand can be obtained from another bank not far away. Sometimes where the sand is largely of quartz composition, but contains a small percentage of deleterious organic matter, it may be brought up to standard requirements by washing in special apparatus. For instance, in one case, 1 : 3 mortar testing 40 lb. per sq. in. tensile strength at seven days with unwashed sand, tested 180 lb. with the same sand washed. Just at the present time we are making a series of tests with a sand of poor quality to determine whether a special brand of cement can be selected which will give good results. In this case advance tests indicate that a certain brand, a different one from that selected by Mr. Hazen, gives acceptable tests, whereas the strength with other cements is much lower.

Mr. A. W. Parker. — What was the occasion for filtering this water — was it muddy, or what?

Mr. Lochridge. — I think we do not want to go into too many questions as to our supply there in this discussion of cost, as that brings in another subject. The principal object in filtering was to obtain as good water as anybody else has. We had pretty good water with the construction of the new supply, without filtration, but in laying out the various features of the new system we found it was possible to include filtration, and it certainly gives to us at all times a safe and very nice-appearing water. It was simply a matter of expediency.

Mr. Desmond FitzGerald. — What is the daily consumption?

Mr. Lochridge. — About 11 000 000 gallons. The filter plant was designed for 15 000 000 gallons, — other features of the supply for larger quantities.

Mr. FitzGerald. — Is it a highly colored water?

Mr. Lochridge. — At times, and at times only. The effluent we have maintained at a comparatively low color at all times.

The Chairman. — What is the storage capacity?

Mr. Lochridge. — Two and one-half billion gallons.

Mr. F. L. Fuller. — I should like to ask Mr. Lochridge about how much water is filtered per acre per day.

Mr. Lochridge. — Well, three acres filter 11 000 000 gallons, and of this usually a half acre is out of commission. Although we planned to run higher rates, that is as high as is desired. We find we hardly ever get a bacteria count up to 10 per cu. cm.

Mr. FitzGerald. — What are the dimensions of these filters?

Mr. Lochridge. — Ninety-one by 260 feet, one-half acre.

Mr. FitzGerald. — How long were centers kept in?

Mr. Lochridge. — That varied. I believe there were forms required for one sixth of the total area. It was arranged that the last two rows should be left in until after the placing of the concrete beyond them, so that there would be two lines of forms left in along the edge of the concrete. The question of season and appearance went as far as time on forms.

Mr. William S. Johnson. — There are many things of great interest in this paper, and some of the points are of enormous value to those who are in this line of work. I was particularly impressed with Mr. Gow's statement in regard to the number of forms required for the construction of the piers and roof. He had prepared, he says, twice as many forms as were necessary, and these added very materially to the cost of the work. Of course there have been several notorious cases where the number of forms provided has been insufficient, but, on the other hand, I believe in many cases the number of forms required has been much too large. As far as safety is concerned, by diagonal bracing the thrust can be taken up without much difficulty so that a great number of forms is not necessary on this account. If the work is so handled that the concrete can be placed in other portions of the work while the forms are being changed, there should be no delays due to lack of forms. In my own practice I permit the contractor to use his judgment in regard to the number of forms, simply giving him the benefit of my experience. I do insist on proper diagonal bracing so that there can be no possibility of failure before the roof is completed, and require that the forms shall be left under two completed bays.

The cost of the concrete in the groined arches, including the cost of the forms, is much lower than is usually bid for this class of work, and I am very glad to have these figures given in such detail, as many contractors have in the past seemed to be unnecessarily afraid of the groined arches on account of the great cost of the centers. In South Norwalk, Conn., we found that one carpenter, — not a union carpenter, — who worked ten hours a day, could make one of the triangles Mr. Gow speaks of in two thirds of a day, that is, he could make the forms to cover the space between four columns in less than three days. The labor on all of the forms for the South Norwalk filters, including those required for walls, piers and roof, and including all labor of setting up and moving, but not including lumber, amounted to sixty-eight cents per cubic yard of concrete. These filters were about half the size of the Springfield filters.

In regard to obtaining sand, I had one experience that seems to go ahead of that of Mr. Gow. No sand could be discovered within about seven miles of the filter, and the railroad was many miles away. There was, however, a gravel deposit just a mile distant across country, and we finally, after extended investigations, decided to use the sand contained in that gravel. To obtain one yard of sand it was necessary to handle something more than three yards of material, and the screening was all done by hand, as the circumstances were such that it did not seem to be economical to put in a mechanical screen. Then a new road, a mile in length, was built across country and the sand was hauled to the site of the filter. After reaching the filter it had to be washed to remove the fine material and dirt, taking out about 5 per cent. in the process. The cost of the sand placed in the filter was about $2.45 per cubic yard.

The washing at this place was of necessity done inside of the filter, as the wash water was obtained by gravity from a reservoir, and the head was not sufficient to deliver any considerable quantity of water above the roof of the filter. At first we thought the location of the washing apparatus inside of the filter was going to be a disadvantage, but it proved to be the opposite.

The sand was dumped through one of the manholes into a hopper which fed directly into the washer, and the dirty water was carried off through one of the drains. The clean sand was discharged into wheelbarrows on a plank run, and a constant stream of wheelbarrows passed the outlet of the washer. The sand was not deposited in layers, as in the case of Springfield, but the material was deposited to the full depth. The plank run

was just above the surface of the sand, so that the drop was small, and the sand was just wet enough so that it would not roll and yet did not pack.

We figured out how many miles the Italians walked on that plank run in a day, and it amounted to about twenty miles. The climate in the filter was cool and decidedly moist, and there was no temptation to stop work. Moreover, there was only one plank, and no one man could stop without stopping the whole work, so that the whole line kept moving continuously. The cost of washing sand is ordinarily very small, and as a much better quality of sand is likely to be secured by washing than can be obtained in a natural bank, it is not wise to go to any great expense to find a bank which will yield satisfactory sand when sand containing fine material or dirt can be obtained nearer at hand.

I was much interested in what Mr. Gow had to say about trench excavation. In this case the measurement of trench excavation was to be made to imaginary side lines having slopes of one horizontal to two vertical. Theoretically this is right. It makes the price received for excavation depend on the depth of the trench. Practically, however, it does not seem to work out right. I notice that here the average price for trench excavation was $0.92 per cubic yard, although the indications were that the material was of such a nature as to be excavated easily, without sheeting. Taking the average trench which was 7 ft. deep with a bottom width of 4½ ft., the price per running foot for trenching in material which stood up with vertical sides would be about $2.00, which of course is very large. I think the reason for these bids is that it is difficult for a contractor to think of excavation and prices in this way. He sees that a trench is to be 7 ft. deep, and it is reasonable enough to think that he ought to get $0.90 per yard for getting the material out, not realizing that the measurement to the imaginary line, outside of the actual excavation, will give him a much larger sum.

Mr. George B. Francis. — I should like to ask whether it would not be wiser to do such work on a percentage basis instead of letting it out to the lowest bidder.

Mr. Lochridge. — I will say that that question is considered on almost all our work. We did some of our smaller work that way. But on this line of work we decided the other way was best, and then we looked up the men who bid and the firms that bid, and weighed their knowledge of prices, and were pretty well satisfied that we were getting a fair proposition before we accepted it.

Mr. Leonard Metcalf. — I am very glad to have an opportunity to express my personal appreciation of this paper. I think we are singularly fortunate to have this paper from a contractor of the standing of Mr. Gow. We so rarely have figures of this sort from contractors that they are especially valuable to us. Of course, engineers are in the habit of keeping cost records, but we are almost always at a great disadvantage in not being able to get all of the items entering into cost. It has always seemed to me that we were fortunate if we could get within ten per cent. of the actual figures. At least, that has been my own experience. In some cases I know my figures have not been as close as that.

As to the cost of concrete work, isn't it a fact that — referring to the filter walls — the reason for the advantageous figures they got on the filter walls and roof was, in a measure, due to the character of the plant which they had for handling the forms, thus preventing delays which so often go to increase the cost very substantially?

What has been said on the question of test pits recalls to my mind a little experience I had in laying out a small sewage disposal plant. As I remember it, the area of the particular beds in question was, perhaps, not over an acre or an acre and a half. We dug seventeen test pits, which seemed to show advantageous material. But when we came to strip it we had virtually to abandon the site, at least to the extent of carting in sand with a three-mile haul, which made my estimates look rather bad.

The President (Mr. Bryant). — If we are going to tell stories about test pits, I should like to tell one of my own. It beats any told here yet. One of our well-known Boston men was having a little work done at one time. I asked him to let us spend a little money to the extent of digging test pits 50 ft. apart along the line of the street, as I expected rock. He consented. We had the test pits dug 50 ft. apart. I won't say how many, at least ten, possibly twelve, and we didn't find a particle of rock. Without one single exception, when we began construction, we found rock humped up between those test pits.

Mr. Gow, what do you think of Mr. Francis's proposition that such work should be done on a percentage basis?

Mr. Gow. — I will have to confess, Mr. President, that I haven't any well-defined opinion on that subject. I can see very readily where it has both advantages and disadvantages. Personally, at the present stage of the controversy, I am not one of

those who hanker much after day work or the percentage proposition, unless it is on something of a nature so difficult or uncertain that no rational basis of figuring can be found. I think that while there are a good many reasons why percentage work would be desirable for both parties, if carried out in the proper spirit, there are so many reasons why it may not be that I am obliged to agree with the majority of engineers who still stick to the bidding method.

Messrs. Hazen and Lochridge in their discussion attribute such assistance given or concessions made by them or their assistants during the progress of the work to the fact that the contractor on his part rendered such action possible by his willing compliance with contract requirements. This explanation is, of course, very flattering to the writer and is duly appreciated by him. Nevertheless he is not conscious of having put forth greater efforts to fulfill his obligations on this contract than on any other he can remember, while he is satisfied that the general attitude of the engineers and commission was in this instance more magnanimous and helpful than he has been accustomed to receive in the great majority of his contract experiences. That this treatment assisted materially in reducing contract costs of many of the items, there is no question. It may be considered by engineers, possessed as they usually are with a commendable desire to safeguard the interests of their clients, whether such interests are not best served by inducing low bids from contractors, based upon their reputation for fairly and liberally interpreting their specifications, thereby making possible low costs to the contractor and consequently low bids to the owner. As illustrating this principle, the cost of rolled embankment as shown is interesting. Based upon his own experience and that of others with which he was familiar, the writer bid \$0.16 per cu. yd. for this item, which to his mind was a very low bid for this class of work if done under the usual engineering requirements of the locality. He was encouraged to bid low by the generally favorable tone of the specifications and by the friendly attitude of the engineers who explained conditions to him. The final cost of \$0.114 per cu. yd. indicates that he even underestimated the value of these features as affecting the cost of this item of the work.

Since the completed dam is the equal in efficiency of any of which the writer has knowledge, he deems it a fair conclusion when he assumes that the owners of the other similar structures must have paid from \$0.03 to \$0.06 per cu. yd. for the high standard of requirements set by their engineers.

In regard to the question raised in discussion concerning the time of striking roof centers, it should be said that, since there was an excess of forms, a sufficient time usually elapsed before removing to more than insure safety. This time varied from ten days to three weeks. At times, however, for special reasons, it was desired to remove certain sections of roof forms in a much shorter time and this was permitted when in the judgment of the resident engineer the concrete had attained a sufficient set to warrant it. On some occasions small sections were removed in three or four days, the test being whether or not the concrete appeared hard enough as determined by actual examination.

The writer is glad to have Messrs. Lochridge and Hazen bring out the details of the final allowance by the water board of the additional expense involved in securing and preparing filter sand of proper quality. No effort was made by either party to determine the legal status of the subject, but it was adjusted as a purely moral claim, the justice of which was never questioned. Public boards are not in general favorable to the recognition of moral claims of contractors, and are even apt in many cases to test legal claims in the courts. The responsibility of this attitude on their part for the antagonistic attitude of many contractors may be more marked than is generally supposed.

[NOTE. — Discussion of this paper by Morris Knowles and F. E. Field will appear in the JOURNAL OF THE ASSOCIATION for February, 1911. Further discussion, to be published at the same time, is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, before February, 1911.]

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DISCUSSION OF PAPER, "THE CONTAMINATION OF CITY AIR."

(VOLUME XLV, PAGE 45, AUGUST, 1910.)

DR. S. ADOLPHUS KNOPF.* — There is very little of practical value that has not been touched on in Dr. Soper's admirable contribution. All that can be done is to amplify some of the interesting suggestions that have been made. He has kindly referred to my remedy for the smoke nuisance, which would consist in installing a smokeless furnace wherever there is a smoke-producing one. Dr. Soper spoke of the unique enterprise mentioned by me to further the sale and use of a certain smokeless furnace. The consumer pays the firm the amount of money which he saves in the consumption of coal over the ordinary method. As stated in my paper, "What may be Done to Improve the Hygiene of the City Dweller," † I do not know of any better means than this peaceable and profitable method of inducing manufacturers and apartment-house owners to obey the anti-smoke laws.

We must, however, not only diminish the smoke coming from stationary furnaces, but also do away with the clouds of black smoke which come from locomotives puffing in and out of our cities and towns. This kind of smoke nuisance can be remedied by insisting that all incoming and outgoing trains for a certain distance beyond the city limits must be drawn by electric engines or by what is called the fireless locomotive.

Since even sterile dust from the wear and tear of the pavements and from building material, if inhaled in quantities, is apt to irritate the delicate membrane of the respiratory tract and thus make it more susceptible to the invasion of pathogenic germs, — such as the tubercle bacillus causing consumption, the pneumococcus causing pneumonia, the Pfeiffer bacillus causing grippe, etc., — the necessity of the sprinkling and proper cleaning of streets insisted upon in Dr. Soper's paper is self-evident. Street-car companies should be obliged to have the car tracks

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† Address delivered before the Section of Municipal Health Officers of the American Public Health Association in Richmond, Va., October 21, 1909, published in the *Medical Record*, New York, January 8, 1910.

sprinkled regularly throughout dry weather; this they can easily do by running sprinkling cars on the tracks.

Beating carpets in backyards and shaking rugs out of the windows is often a nuisance and should be restricted to certain hours. The use of the pneumatic process should be encouraged and facilitated, and the managers of all public buildings and large establishments should be obliged to use this method of cleaning. The cleaning of schools should be done by the same process. Sweeping and dusting in the old-fashioned way in our school rooms should be absolutely done away with.

What Dr. Soper said in regard to droplet infection — that is to say, the method whereby small particles of saliva containing pathogenic germs are conveyed from one person to another during the act of coughing or sneezing — is true. There is particular danger from this when any one is standing or sitting in close proximity to the person who coughs. The droplets are seldom expelled more than three feet; beyond this distance they fall to the ground and the danger from them is of course less. But, as was pointed out by Dr. Soper, the crowded street car is the place *par excellence* to catch the germs through droplet infection.

Dr. Soper's suggested remedy is unfortunately difficult to carry out. I will quote what he said regarding this matter: "I have said, perhaps without the approval of some of my hearers, that men, women and children who are suffering from the lesser respiratory diseases should stay away from crowded assemblages. I think this precaution is a matter of much importance. It is good for the person who stays away, and better still for the others. It is a common thing in New York, when traveling back and forth in the overcrowded public conveyances, — and I think we get a pretty good example of how overcrowded they can be, — to see men standing and coughing directly down into the faces of those who are so fortunate, or unfortunate, as to have seats."

The first slight criticism I would wish to make is that I can't quite understand why he only wishes the people with "lesser" respiratory diseases to stay away from crowded assemblages. He probably refers to all respiratory diseases with the exception of tuberculosis, yet the pneumococcus and the grippe bacillus can prove quite as dangerous. But even granted that pneumonia and grippe should be less dangerous, why not have those afflicted with tuberculosis also stay away from crowded assemblages?

There is a wrong conception in the minds of many that it is

only the consumptive in the latter stages of the disease who is a real danger to his fellow-men. I venture to differ from this view. The consumptive in the last stages of the disease is more often confined to the four walls of his room, which he may or may not infect according to his training and good-will. But the greatest disseminator of the tubercle bacilli is the consumptive up and about, working steadily or doing odd jobs, mingling with the population at large. If he is not careful and conscientious, he may deposit his bacilli-laden sputum in enough places in twenty-four hours to be the cause of a goodly number of infections.

To overcome the danger of droplet infection, to minimize this source of communicating respiratory diseases, it would not suffice to tell people afflicted with the "lesser" or more severe respiratory diseases to stay away from crowded assemblages. The majority of those afflicted can ill afford the luxury of a private car, automobile or carriage. Many people, even when afflicted with colds or real grippe, or when in the earlier stages of tuberculosis, are still obliged to work in order to support themselves, and travel in crowded cars to and from their crowded workshops or offices.

Aside from all this there is something which is not universally known but which is, nevertheless, an established fact, namely, that even a healthy person may carry in his mouth the pneumococci which, when they reach a favorable soil (a strongly predisposed individual), may cause the development of pneumonia. Therefore, I believe, the best remedy is to teach our children at home and at school, our friends and our employees, and to learn ourselves, to hold a hand or handkerchief before the mouth when coughing or sneezing. To our public signs and placards prohibiting expectorating on the floor should be added a phrase reading somewhat like this: "When coughing hold a handkerchief before your mouth. Disease germs may be contained in the small particles of saliva which are expelled during the so called dry cough."

Reference was made in Dr. Soper's paper to the subway air. Thanks to the splendid work of Dr. Soper we all know now of the excess of carbon dioxide in subway air, and particularly during rush hours, and we know also that the principal mineral constituent of that air comes from the small particles produced by the wear and tear on the brake shoes, iron rails and wheels. Those who suffer most from the dangerous and irritating dust are not the passengers who remain within the cars for a short space of time. but the track-walkers, conductors and

car-men, ticket-sellers and ticket-choppers. The special hard steel made for the rails, mentioned by Dr. Soper in the discussion, may to some degree lessen the quantity of iron dust in the subway air, but there will be, to my mind, still a sufficient amount of iron dust in the air to endanger the health of the employees working constantly in that atmosphere.

Besides more ventilation, the only way I can see of diminishing the danger to which these employees are exposed is to have all those who can, wear protective respiratory masks. All of them should regularly alternate their service with the employees of the elevated or surface cars wherever the combination of the companies makes this possible.

In conclusion, while I do not exactly differ from my friend Dr. Soper when he speaks approvingly of Hessler's idea of the danger of winds to the health of human beings, I would wish also to show the beneficial action of winds. If there ever was a windy city it is certainly Chicago, yet Chicago is one of the healthiest cities in the United States, and while I gladly bear homage to the men at the head of its excellent sanitary supervision, and particularly to my good friend, the honorable commissioner of health, Dr. W. A. Evans, there is no doubt in my mind that the wind to which the city of Chicago is so much exposed, and which sweeps away all poisonous gases, is in no small degree responsible for its healthy condition. Let the builders of future cities bear in mind that a city situated on high ground, with wide streets where the winds can sweep through, will be a healthy city and relatively free from tuberculosis, pneumonia, grippe and other infectious diseases of the respiratory organs.

With my lamented master, Geheimrath Professor Dettweiler, I claim that not too violent winds ("*bewegte Luft*") are rather beneficial than detrimental to tuberculous and similarly afflicted patients. In existing cities the widening of streets and the lowering of too high buildings will help the freer circulation of air, and the admittance of sunlight will very materially improve the sanitary condition.

Prof. C.-E. A. Winslow. — The Society is very fortunate in being able to present this paper to its members. Dr. Soper's original investigation of the air of the New York Subway was, I think, unique in the care with which analytical methods were devised and in the thoroughness with which they were applied. It is one of the most exhaustive studies of air supply with which I am familiar in any literature. It is particularly fortunate, too, that in connection with this summary of his more important results,

Dr. Soper should have given us also such an excellent discussion of the general principles of air supply in its relation to the public health.

I have nothing to add in regard to what is so well said in the paper in regard to the dust and bacteria in the air. I should, however, like to emphasize one point to which Dr. Soper refers only briefly. The quality of bad air which we know to be chiefly important — the only quality, in fact, in regard to which we have any clear-cut experimental evidence of danger to health — is the physical quality of high temperature combined with moisture. Even here we much need further investigation, for the study of the hygiene and sanitation of the air has been perhaps the most neglected of all branches of sanitary science. It is very clear from Professor Haldane's English experiments that the crucial test of the quality of air is a reading of the wet-bulb thermometer. While very high temperatures can be endured if the air be dry, Dr. Haldane showed that moderate physical work led to a marked rise in body temperature as soon as the wet-bulb temperature passed 78 degrees. If at this point the mechanism of the body is so seriously upset that practically a condition of fever sets in, we may be sure that long before this there is not only discomfort, but actual danger. It is probably safe, in the light of all the facts, to set 70 degrees on the wet bulb as a danger point which should never be exceeded. Dr. Soper does not give the wet-bulb temperatures directly, but from figures for dry-bulb temperature and relative humidity published in the *Technology Quarterly* several years ago, it appears that during October, 1905, the wet-bulb temperature in the subway was occasionally at least between 75 and 80. It would be of great interest to obtain readings indicating the present conditions in the subway, but the extreme discomfort one experiences in using it during rush hours is sufficient evidence that conditions are still exceedingly bad. I talked only last week with a friend who has moved his office and ceased using the subway, and he told me that his life is a different thing in consequence, for under the old conditions he found himself every morning dull and listless and stupid as a result of the morning descent into the Inferno. I have no doubt whatever that the abominable conditions which still exist are responsible for as much disease and discomfort as any single factor in the health of New York City.

Dr. Geo. A. Soper. — Dr. Knopf's remarks are of peculiar value, coming as they do from probably the best-known tuberculosis expert in America. I agree with him in hoping to see the

smoke nuisance abated. Occupying an office in the lower part of Manhattan Island, close to the water front, with a broad view, I am well able to see the unpleasant, not to say unwholesome, effects of soft-coal smoke. Particularly noticeable is the smoke of vessels, chiefly tug boats. Ships of the United States Navy are often offenders in the matter of producing black smoke from their funnels. That the production of black smoke from vessels is not necessary is evidenced by the fact that most of the craft upon the harbor are innocent of this offense.

The production of smoke, like the beating of carpets, sprinkling of streets, excessive sanding of car tracks, the dusting of museums and other public places in the presence of visitors are practices which are unfortunately too prevalent. With such valiant champions of sanitation as Dr. Knopf and Professor Winslow these customs once thought indispensable will some day be regarded as remnants of a past civilization.

With respect to droplet infection, my belief is that there is danger beyond the 3-ft. limit which Dr. Knopf indicates. Beyond this distance from the person who produces them, most of the germs rapidly fall to the ground, but it has been shown by investigators that some remain in the air for a considerable time. Still, they do not go as far as one might think. The well-known law with regard to the dispersion of light, heat and sound, that the effect produced varies inversely with the square of the distance, might be supposed to apply here. The fact is, however, that the weight of the germs, slight as it may seem, is sufficient to cause them to settle rapidly beyond the 3-ft. limit.

A slight misunderstanding exists in Dr. Knopf's mind concerning my use of the term "lesser respiratory diseases." By this term I do not refer to all respiratory diseases with the exceptions of tuberculosis. I think pneumonia and diphtheria should at least be termed major diseases. When I said lesser respiratory diseases, I meant grippe, bronchitis and that variety of affections included in the general and misleading term "common cold." I would have people suffering from the major respiratory diseases as well as people ill of the lesser respiratory diseases stay away from crowded assemblages. People suffering from tuberculosis should by all means be kept away from crowded places where they are practically certain to transmit their disease to others.

The difficulty of separating germ producers from their fellow-beings lies not in determining who should be separated, but how separation can be effected without producing undue

hardship. A person is often able to do a substantial amount of work while at the same time he is a living germ factory. I do not pretend to know how this situation can be met. Other and more competent persons have given a great deal of time to its study. I merely wish here to emphasize the contagious nature of practically all respiratory diseases and to urge that those who are known to be suffering from any of them refrain from visiting crowded places as much as possible. What Dr. Knopf says about consumption in its mild stages is equally true of all other diseases which are transmissible through air.

To Dr. Knopf's admirable admonition about the handkerchief I would add, Do not shake your handkerchief before using it. This is a common practice and one which should be discouraged.

It is an unfortunate fact that those who suffer most from dust are not always those who are the most exposed to it. Some persons are peculiarly susceptible to injury from this cause while others seem immune from it. The track workers in the New York subway are picked men. They have large lung capacity and they are young and strong. I believe they do not remain long at this work. The track workers probably breathe more dust than any other class of persons who use the subway. The injury produced upon them is probably below the average.

There is no difference between Dr. Knopf and myself with respect to the effect of winds on health. It is conceivable that even a large wind movement such as occurs in some parts of the United States may be beneficial to health, although it is difficult to understand just how much wind is required. It is certain that without some movement of wind, life on the earth would be unendurable. We count upon natural movements of air to ventilate our cities. Our streets and houses are ventilated, not by artificial means, but by currents of air which are set up by the movement of wind from one point to another. It is surprising to see how thorough is this effect. Wind penetrates our clothing and our homes no matter how closely we may be locked up.

There is a difference between wind and draughts. My remarks concerning the possibly injurious effects of too much air movement in a subway station refer to the piercing currents of cold air which form draughts. Dr. Knopf, I am sure, will agree with me that a strong current of air, relatively small in volume and differing materially from the surrounding temperature, is not a wholesome thing to encounter and that when this condition is indefinitely repeated it may become dangerous.

Professor Winslow has called attention to a subject of large and growing importance in the matter of air analysis; that is, the part which humidity plays in affecting the health and comfort of human beings. We all know that cold and heat can be borne even when extreme, provided the air is not damp, as we say. We are so familiar with the sultry days of summer and the raw weather of winter along our coasts that it is unnecessary to speak of the disagreeable sensations which result from dampness. Most of us have a vague belief that damp weather, be it hot or cold, is unhealthy, but to many it will be new that a definite degree of humidity should have been determined beyond which injurious consequences to health result.

So far as the New York subway is concerned, the relative humidity was less in the subway than outside, and for a simple reason. The absolute humidity was about the same, but the greater heat in the subway made the relative figure less. Relative humidity means, of course, the amount of aqueous vapor which was present compared to the greatest amount which could be present, this ratio being expressed as a percentage.

The general air of the New York subway was found to be fairly good, in my investigations, except for the metallic dust. The dust could largely be prevented by the use of fiber brake shoes. Such shoes have been successfully employed in Europe, but, as far as I know, have never been used in American subways. They have many mechanical advantages and are said to be fully as economical as metallic brake shoes. Fiber brake shoes are more sanitary than iron brake shoes because their dust is less harmful than iron dust.

Just how much harm was being produced by the dust in the New York subway could not be determined during my investigations because the subway had not been in use for a sufficient time for the evil effects to become manifest, even though a good deal of injury was being done. I therefore recommended that the investigation be supplemented by some further studies at the end of a few years. It is time that this supplementary work was done.

Professor Winslow has spoken in strong terms of the unhealthfulness of the New York subway. I am compelled to agree in thinking subways unhealthful. They are unhealthful chiefly when they are overcrowded. In this respect they are like theaters and other enclosed spaces where people congregate in great numbers and without adequate room. Subways are worse than other places because there people are in closer contact and

there are more people to be affected. It is impossible to be sanitarily safe in such close bodily contact as now occurs in the New York subway. No amount of ventilation practicable can overcome the danger. The conditions are ideal for the transfer of respiratory and some other diseases. The germs in unimpaired, viable condition pass from one person to another quickly.

Only persons who have had experience in the New York subway during the busy hours can realize how great is the crowding and with what an appearance of equanimity and good nature the conditions are tolerated. The following account of a recent experience of the president of the Public Service Commission is taken from the New York *Evening Post* of December 5, 1910:

"One of ten thousand people who were man-handled to-day in the subway was William R. Willcox, chairman of the Public Service Commission.

"Mr. Willcox left a local train at Fourteenth Street and crossed the platform, intending to board a downtown express. He was caught in the rush of feverish people and swept forward to the door of a car. He did not get any further. A voice shouted "All aboard," and the strong arm of a special policeman — a subway husky — shot out and met the public service chairman just below the chin. With the other the husky closed the car door, and awaited the next rush.

"The treatment which Mr. Willcox received was not different from that meted out to hundreds of subway travelers every day, but he did not make a second attempt to board an express. Instead he retraced his steps across the platform to the local train, after straightening his hat and collar."

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DISCUSSION OF PAPER, "THE PRACTICAL QUESTIONS CONCERNED IN THE COLLECTION AND DISPOSAL OF MUNICIPAL WASTE."

(VOLUME XLV, PAGE 73, SEPTEMBER, 1910.)

MR. SAMUEL A. GREELEY. — The writer read this paper with much interest and pleasure. There was one point in the paper that seemed particularly good. On page 90 occurs the statement that "what is needed in this work is a standard method of analysis, which should give the determinations in a form that can be readily used for comparison at other places." This lack of standard data is evident all through the subject of refuse collection and disposal. As Mr. Emerson indicated in his discussion, a great many claims and misleading statements regarding special methods of disposal have been made and have been given credence by those unfamiliar with the details of the work. A standard form of statistics somewhat similar to that prepared for water works by the American Water Works Association would be highly desirable.

This lack of system in studying the question of refuse disposal crops out in other phases of the work. This is apparent in the several examples of loosely drawn specifications which have resulted in such wide variations in the amounts of the bids made for the work specified. Likewise the construction work in garbage plants seems to have met with a similar fate. One of the reasons for lack of efficiency in garbage disposal comes from the failure of the structures in certain important features to withstand the special conditions for which they should be adapted. Frequently the bracing and bonding of the furnace structures are inadequate and allow the brickwork to open, giving opportunity for cold air to leak into the furnace and so to correspondingly reduce the temperature. The layout of fire-brick grates has often been the cause of high cost for repairs, due to lack of care in the selection of materials. Castings for the furnace fronts have been made so light that they cannot withstand the changes of temperature to which they are subjected.

With regard to the cost of operation, Mr. Emerson's statement in regard to this is one that should not be overlooked. The history of garbage disposal in Milwaukee offers a particularly

good opportunity for comparing two systems of disposal, namely: (1) Disposal by burning with the addition of coal, the garbage alone being burned; and (2) the disposal of garbage mixed with other refuse without the use of additional fuel. The following table shows the comparative results of operation for five months under the two systems. Up to the spring of 1910, the garbage of Milwaukee was burned in an Engle crematory, using coal. Since May 12, 1910, all the garbage has been burned at the Refuse Incinerator.

MILWAUKEE REFUSE INCINERATOR.

Data for first five months' operation, 1910.

	Total Quantity, Tons.	Average per Day, Tons.	Per Cent. Garbage.	Per Cent. Ashes.	Per Cent. Rubbish.	Per Cent. Manure.	Total Cost Disposal of Garbage, 1909.	Cost Disposal of Refuse, 1910.*	Balance in Favor of 1910.	Cost per Ton of Refuse, 1910.†
			(All	by	wei	ght)				
June‡	5 170	198	59	25	9	3	$5 691.60	$4 956.04	$735.56	$0.96
July	4 760	183	67	17	11	5	6 451.84	5 146.48	1 305.36	1.07
Aug.	4 861	180	71	14	12	3	6 662.64	5 074.96	1 587.68	1.04
Sept.	5 341	205	67	20	11	2	6 914.24	4 698.74	2 215.50	0.88
Oct.	5 370	206	64	22	12	2	5 453.60	4 405.21	1 048.39	0.82
	25 502	194	66	20	11	3	$31 173.92	$24 281.43	$6 892.49	

This table shows, at least for Milwaukee, that burning garbage mixed with refuse is cheaper than to burn it with coal. It will be seen from the table that the cost per ton has been reduced somewhat, and it is probable that further reductions could be made, although to what extent it is not now possible to state. Mention should also be made of the fact that the cost of hauling ashes and rubbish has been reduced by the accessibility of the point of delivery furnished by the new plant.

One feature of the table which deserves comment relates to the composition of the refuse burned. It will be noticed that during the summer months, the refuse contained from 60 to 70 per cent. of garbage, and that the lowest proportion of garbage amounted to 59 per cent. of the total. It is the writer's experience

* Costs for 1910 do not include oil, waste, repairs, etc., amounting to $1,281.66 for six months, about half of which represents permanent improvements.

† Quantities of garbage greater in 1910 than in 1909 by about 8 per cent.

‡ During June, 4 per cent. of the total quantity of refuse was street sweepings.

that it is about as difficult and costly to burn 200 tons per day of refuse containing 70 per cent. of garbage as it would be to handle a larger quantity containing a lower percentage of garbage. In other words, the proportion of garbage or other incombustible in the refuse really controls the rate of burning and consequent cost nearly as much as does the total quantity or bulk. It would be interesting to know the cost of burning the garbage as distinct from burning the refuse as a whole. It is evident, therefore, that it will be desirable to know the proportion of incombustible and moisture in the refuse before giving the furnace its rating on a basis of tons per day.

Referring to Table 9 of Mr. Morse's article, which gives the test cost of operation of the Milwaukee incinerator, it should be stated that this cost was determined under conditions clearly stated and artificially created by the terms of the specifications. They do not, and were never intended to, represent the normal operating conditions of the plant. To this extent they are misleading and should not be quoted except when reference is also made to the specifications controlling them. For example, the cost of unloading the refuse and delivering it into the storage hoppers was purposely ruled out of the test. Also the handling of the clinker except inside the building was not included. Naturally, no repair work or general labor on maintenance is included.

The writer wishes again to express his pleasure at having read this paper, and trusts that more care and systematic study into the problem of refuse disposal will result.

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PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 18, 1910. — The 687th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, May 18, at 8.30 o'clock, President Holman presiding. The total attendance was 41.

The minutes of the 686th meeting were read and approved.

Letters were read from the Louisiana Engineering Society, in connection with legislation pertaining to the status of civilian engineers in the United States Army, and from the Missouri Tax Conference. The letters were ordered filed.

Mr. Philip Aylett, Principal Assistant of the Municipal Free Bridge, then presented a paper on "The Disadvantages of Rigid False-Work: Its Successful Elimination by a New Method Employing Suspended Flexible Centering." The paper was plentifully illustrated by lantern slides, many of them showing the method as applied to the construction of the Chickahominy River Bridge, at Richmond, Va.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, June 1, 1910. — The 688th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, June 1, at 8.30 o'clock, President Holman presiding. There were present 28 members and 11 visitors.

The minutes of the 687th meeting were read and approved.

On motion of Mr. Schuyler, seconded by Mr. Hendrich, it was voted that the President be empowered to appoint a committee of five members to determine the advisability of discontinuing the connection of the Engineers' Club of St. Louis with the Association of Engineering Societies. The vote showed 15 ayes and 9 noes.

The Secretary presented the following amendment to the by-laws, to be submitted to vote at the next meeting in accordance with the by-law covering amendments:

Substitute for the present Section 6 the following:

SECTION 6. *Meetings and Papers Committee.* The Meetings and Papers Committee, appointed in the manner herein described, shall prepare a program for each meeting, and shall have the power of passing upon the character of all papers prior to their presentation before the Club, and of deciding upon their fitness for publication in the JOURNAL. The Meetings and Papers Committee shall consist of three members, who shall be appointed, one each year, by the President, and of whom one shall retire at the end of each fiscal year, in rotation.

The Secretary presented his resignation of that office, as well as of that of Librarian and member of the Executive Committee, the resignation to take effect September 1, 1910.

Mr. H. K. Smith, chief electrician of the Pacific Division, Panama Canal, then presented an illustrated address on "Construction Plants and Electrical Equipment of the Pacific Division of the Panama Canal." Many lantern slides were exhibited, showing the generating plant and substations, and of the electrically driven cranes and conveying machinery used in the construction of the locks and retaining walls.

The meeting then adjourned to the adjoining rooms, where the Entertainment Committee had provided refreshments.

Adjourned.

A. S. LANGSDORF, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, JUNE 15, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock P.M., President Henry F. Bryant in the chair, 90 members and visitors present.

The records of the regular May meeting and of the adjournment thereof were approved as printed in the June *Bulletin.*

Messrs. William W. Bigelow, John M. Cashman, John F. Connell, Samuel L. Connor, Frederick C. Dashper, Charles A. Fritz, Charles H. Getchell, Harry R. Hall, Robert B. Jeffers, Edward T. Murphy, Jewett B. Newton, Charles H. Restall, Walter F. Robinson, Fred E. Tibbetts, Philip B. Walker, Henry E. Warren and Frank S. Wilson were elected members of the Society, and Messrs. Burton M. Lawler and Charles F. Templeton as associates.

The Constitution as adopted at the meeting of May 25, 1910, and sent out with the notice of this meeting, was, on motion duly made and seconded, adopted for the second time as required by the present Constitution, 28 members voting in the affirmative and 3 in the negative.

Amendments offered by Mr. Higgins — striking out the words "other" and "shall not be eligible as Associates," in the fifth paragraph of Article II of the Constitution, and inserting at the beginning of the paragraph the words "Associates shall be" — were rejected. Amendment to Article V, — striking

out the word " regular " in the fourth line, — offered by Mr. Higgins, was also rejected. While Article V was being further considered, the discussion was brought to a close by the adoption of a call for the previous question, on motion of Mr. Sherman.

The consideration of the proposed code of by-laws presented at the meeting of May 25, 1910, and sent out with the notice of the meeting, was then taken up. After discussion it was voted unanimously to adopt the by-laws as printed, excepting by-laws 5, 7, 9 and 13.

During the discussion, the time for the literary exercises having arrived, further consideration was postponed until the conclusion of those exercises.

By-law 5 as printed, after the rejection of an amendment striking out the words " one or more," in the sixth line, and inserting the word " three," was itself rejected, 17 voting in the affirmative and 10 in the negative, not the necessary two thirds.

By-law 7 as printed was amended on motion of Mr. Higgins by striking out the words " at least " in the tenth line of the second paragraph and inserting the words " less than " in place thereof, and also by striking out the words " do not," in the eleventh line of the same paragraph. An amendment providing for election by letter ballot, instead of by vote of the Board, was rejected. The by-law as amended was then adopted unanimously.

After the adoption of an amendment offered by Mr. Howe, striking out the last four lines of by-law 9 as printed, the amended by-law was rejected. Later the matter was discussed further, and after the insertion, at the end of present by-law 11, of the words, " Any such appropriation or any part thereof not used within three years shall be returned to the fund," the by-law was adopted, with the understanding that it shall be number 9 of the new by-laws.

By-law 13 as printed was also adopted after a discussion by Mr. Howland as to the advisability of continuing sections within the Society.

After a general discussion of the subject, on motion of Mr. Howe, it was voted," That the by-laws passed this evening, including by-law 5 of the present code, be adopted as the by-laws of the Society," 25 voting in favor and 1 against.

The President stated that in answer to a communication from the joint Committee on Club-House and Society Headquarters, the Board of Government recommended the passage of the following votes:

1. *Voted:* That the Society approves the general scheme for the Proposed Society Headquarters and Engineers' Club, as outlined by the Joint Committee in its circular dated June 6, 1910.

2. *Voted:* That the Society desires quarters in such a building as is proposed, and is prepared to pay a total annual rental not exceeding $2 500 therefor, in addition to salaries of independent or joint officials.

3. *Voted:* That the Society advocates the joint maintenance and use of its library with those of other societies, but desires, so far as practicable, to preserve an independent ownership of books and periodicals.

Also that the Society desires the joint use of social rooms for all its members, but is unable to offer any additional rental above the amount specified in the second vote.

4. *Voted:* That it is the opinion of the Society that its members individually or collectively will actively interest themselves in securing tenants for any headquarters building of approved design and location.

After amending vote 2 by striking out the amount of rental named and leaving the amount to be inserted to be determined by the Board of Govern-

ment, the several votes were passed, on motion duly made and seconded for each vote.

On motion of Mr. Rollins it was *Voted:* That the representatives of the Boston Society of Civil Engineers on the Board of Managers of the Association of Engineering Societies are requested to confer with the Committee of the Engineers' Club of St. Louis appointed to consider the withdrawal of the Society from the Association, and to report their recommendations in the September *Bulletin.*

The literary exercises of the evening consisted of a description of the methods of repairing and resurfacing streets and highways by the Lutz Surface Heater, by Mr. B. B. Colborne, representing the Equitable Asphalt Maintenance Compay, of Kansas City, Mo. The description was illustrated by motion pictures showing the process in complete operation in Washington, D. C., and by a large number of lantern slides showing the results of the use of the method.

A vote of thanks was extended to Mr. Colborne for his interesting description.

The meeting adjourned at 11.15 P.M.

S. E. TINKHAM, *Secretary.*

// ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XLV. **OCTOBER, 1910.** NO. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, SEPTEMBER 21, 1910. — The 689th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday evening, September 21, 1910, at 8.30 o'clock, President Holman presiding. There were present 37 members and 4 visitors.

The minutes of the 688th meeting were read and approved, and the minutes of the 480th and 481st meetings of the Executive Committee were read and approved.

Mr. Woermann moved that memorials be prepared of Beriah Warren, Charles F. Foster, Phillip Florreich. Upon suggestion, President Holman agreed to appoint members of the Club to prepare these memorials.

The President then called for nominations for Secretary and Librarian, to fill the vacancy caused by the resignation of Professor Langsdorf. Mr. Schuyler nominated W. W. Horner. There being no other nominations, Mr. Wall moved that the nominations be closed and that the Secretary be instructed to cast the ballot for Mr. Horner. Motion seconded and carried. Secretary announced that the ballot had been cast.

It was moved, seconded, and carried unanimously that the Club extend vote of thanks for faithful and efficient service to retiring Secretary, Professor Langsdorf.

Professor Langsdorf moved that the amendment to Article VI of the By-Laws, as presented at the meeting of June 1, 1910, be adopted. Amendment read as follows:

"SECTION 6. *Meetings and Papers Committee.* The Meetings and Papers Committee, appointed in the manner herein described, shall prepare a program for each meeting, and shall have the power of passing upon the character of all papers prior to their presentation before the Club, and of deciding upon their fitness for publication in the JOURNAL. Meetings and Papers Committee shall consist of three members, who shall be appointed, one each year, by the President, and one of whom shall retire at the end of each fiscal year, in rotation."

The amendment was amended by addition of the following: "Provided that before October 1, 1910, the President shall appoint three men, one of whom shall retire at the end of 1910, one at the end of 1911, and one at the end of 1912."

The amendment as amended was carried by a vote of 27 ayes to 4 noes.

The applications for admission to the Club of the following were read and referred to the Executive Committee:

Members — Arnold Dettmar Alt, William McK. Brown, Eugene L. Brown, Jr., Robert Alexander Bull, William J. Crocken, William A. Foley, Karl Sharp Howard, George McDearmon Johns, John Charles Pritchard, George Meredith Peek, Charles Austin Redinger, George R. Gibert.

Associate Members — William Edward Hoblizelle, Ralph Kalish, Edward Prendergast.

Junior Member — John G. Stupp.

Non-Resident Member — Walter O. Pennell.

The report of the committee on "the advisability of withdrawing from the Association of Engineering Societies" was formally presented. At the request of Mr. Von Maur, chairman of the committee, the Secretary read the correspondence of the committee with the Boston Society of Civil Engineers.

Mr. Schuyler moved that the recommendations of the committee be accepted and acted upon. Seconded by Mr. Rolfe. Mr. Flad amended Mr. Schuyler's motion by striking out that portion of the First Recommendation after the word "year" in the 4th line of the last paragraph of the printed report. Mr. Flad's amendment was adopted. Mr. Schuyler's motion, as amended, was then put to vote and carried.

The recommendations of the committee, as amended and adopted, are as follows:

"*First*, that the Secretary be instructed to notify the Boston Society of Civil Engineers in answer to their correspondence on the subject that the Engineers' Club of St. Louis will not withdraw from the Association this year."

"*Second*, That the President be authorized and directed to appoint a committee of seven members, whose duty it shall be to bring the local members of the various national societies together, and to report a general scheme under which all the technical societies of St. Louis can work together harmoniously and for the common good of all. Said committee shall report to the Club on the first meeting of every month until its work shall have been completed."

Mr. Metzger made an announcement of the Convention of the American Society of Engineering Contractors, and suggested that the Club send a note of welcome. Mr. Bryan moved that the matter of entertaining and welcoming the convention be referred to the Executive Committee with power to act. So voted.

The meeting then adjourned to the adjoining room, where refreshments were provided by the Entertainment Committee.

Adjourned.

W. W. Horner, *Secretary.*

Boston Society of Civil Engineers.

Boston, September 21, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Henry F. Bryant in the chair, 140 members and visitors present.

On motion duly made and seconded, it was voted to dispense with the reading of the record of the June meeting, and to approve the same as printed in the September *Bulletin*.

The Secretary announced that the following had been elected to membership in the grades named:

Members — Messrs. Arthur B. Barnes, William A. Brown, Arthur N. Coleman, Mark E. Kelley, Patrick J. Malley, William H. G. Mann, Leon O. Norwood, Wilbur C. Otis, Horace W. Oxnard, Theodore Parker, Arthur P. Rice, Clarence W. Rolfe, Horace U. Ransom and Chester E. Taylor.

Juniors — Messrs. Thomas R. Hazelum and Hugh Nawn.

Associates — Messrs. Charles E. Hale, Edgar Knowlton, John M. Lyons, Charles H. Rogers and George E. Towle.

The President announced the death of William Jackson, a member of the Society, which occurred on June 30, 1910. By vote, the President was requested to appoint a committee to prepare a memoir. The following have been named as that committee: Desmond FitzGerald, E. D. Leavitt and F. H. Fay.

The President called attention to the two vacancies in the number of Directors, occasioned by the adoption of the new constitution at the June meeting, and as notice had been given of these vacancies in the call for this meeting, it was now in order to proceed to an election. Mr. Hodgdon placed in nomination Mr. J. P. Snow for the term ending in March, 1912, and L. L. Street for that ending in March, 1911, and stated that he named these members because they were candidates for Directors at the last annual meeting.

On motion duly made and seconded, the Secretary was instructed, by a unanimous vote, to cast a ballot for these nominees for the terms specified. The Secretary having performed the duty assigned him, the President announced that Mr. J. Parker Snow had been elected Director for the term expiring March, 1912, and Mr. L. Lee Street for the term expiring 1911.

The Secretary reported for the Society's representatives on the Board of Managers of the Association of Engineering Societies, that they were in communication with the Committee of the Engineers' Club of St. Louis, which was considering the advisability of that society withdrawing from the Association. Up to the present time, however, the consideration of the matter had not reached a stage which warranted your representatives in making any recommendation. They, therefore, asked for further time. On motion the report was accepted and further time granted.

The thanks of the Society were voted to the Aberthaw Construction Company and to Messrs. Fred T. Ley & Co., for courtesies extended to the members of the Society this afternoon on the occasion of the visits to Lowell, Mass., and Nashua, N. H. The thanks of the Society were also voted to the management of the Aero Meet at Squantum, for courtesies shown our members during the visit to the aviation grounds.

Mr. Louis K. Rourke, superintendent of streets of Boston, and late assistant engineer in charge of construction of the Central Division at the Panama Canal, was then introduced, and spoke of the work at the Canal, with special reference to the organization and methods of construction. The lantern was used to illustrate his remarks.

After passing a vote of thanks to Mr. Rourke for his very interesting talk, the Society adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., October 10, 1910. — The sixth regular meeting of the year was called to order in the Society's quarters in the Old State Capitol Building at eight o'clock p.m. by Vice-President L. P. Wolff. There were present seven members and one visitor.

The minutes of the previous meeting were read and approved.

Upon motion duly made and carried, the Secretary was directed to extend to Col. L. G. Pendergast (custodian of the Old State Capitol Building) the thanks of the Society for the efficient manner in which he had renovated the Society's quarters.

It was regularly moved, seconded and carried that the President and Secretary of the Society transmit a letter in behalf of its members to the President of the United States, setting forth the exceptional qualifications of the Hon. Ira B. Mills (chairman of the Minnesota Railroad Commission) for a place on the United States Commerce Court recently provided for by the Congress of the United States.

The Secretary was directed to communicate with Mr. W. L. Bierd (general manager Minneapolis & St. Louis R. R.) and invite him to give the Society a talk on the Panama Canal, the construction of which he was formerly intimately connected with.

The applications of Mr. George A. Ralph and Mr. W. G. Davies for full membership in the Society were presented and ordered read. Upon motion regularly made and seconded, it was carried that the Secretary cast the ballot of the Society and elect the applicants as petitioned. The applicants were declared elected.

There being no further business to engage the Society, the meeting adjourned.

D. F. Jurgensen, *Secretary.*

Montana Society of Engineers.

Butte, Mont., September 10, 1910. — The regular meeting of the Society for September was held on the stated date, with President Smith in the chair. Quorum present. The minutes of the prior meeting were approved as read. The Secretary reported that at the request of the president of the National Conservation Congress, held at St. Paul, Minn., September 5 to 9 inclusive, President Smith appointed the following delegates to said Congress: Wm. L. Darling, James H. Ellison, Chas. H. Bowman, Joseph H. Harper and George A. Kenrick. It is believed that most of these delegates were in attendance, having so signified their intention.

President Smith appointed the following Committee on Nomination of Officers for the coming year, to wit: Charles W. Goodale, George E. Moulthrop and Darsie C. Bard. The remainder of the evening's session was devoted to the discussion of the various phases of the Good Roads movement in Montana, and great interest was manifested by the members present.

Adjournment followed.

Clinton H. Moore, *Secretary.*

// Association of Engineering Societies.

Vol. XLV. NOVEMBER, 1910. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 5, 1910. — The 690th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, October 5, 1910, at 8.30 o'clock, Vice-President J. D. Von Maur presiding. There were present twenty-six members and three visitors.

The minutes of the 689th meeting were read and approved with one correction. The minutes of the 482d meeting of the Executive Committee were read.

The following gentlemen were elected to membership:

Members — Arnold Dettmar Alt, Wm. McK. Brown, Eugene L. Brown, Jr., Robert Alexander Bull, Wm. J. Crocken, Wm. A. Foley, Geo. R. Gibert, Karl Sharp Howard, Geo. M'D. Johns, Geo. Meredith Peek, John Chas. Pritchard, Chas. Austin Redinger.

Associate Members — Wm. Edw. Hoblizelle, Ralph Kalish, Edw. Prendergast.

Junior Members — John G. Stupp.

Non-Resident Members — Walter O. Pennell.

Applications for membership from the following were read and referred to the Executive Committee:

Members — Frank Neher, Robt. L. Kneedler, Fred. J. Reinke, Chas. Edw Smith. Robt. M. Strong, Fred. Young.

Mr. Zelle announced that the Entertainment Committee had arranged a trip to the Municipal Bridge for the near future, and moved that the Secretary be instructed to send invitations from the Club to the mayor, members of the Board of Public Improvements and of the Municipal Assembly. So voted.

Mr. Bryan announced that there would be a joint meeting of the Club and the American Society of Mechanical Engineers on Saturday evening, October 15, at which Mr. Frank B. Gilbreth, of New York, would present a paper on: " Fires: Effects on Building Material and Permanent Elimination."

The Secretary read communications from Mayor Kreismann to President Holman in regard to the Engineers' Club assisting in raising funds for the convention of the Lakes-to-Gulf Deep Waterway Association, to be held November 25 and 26. The matter was discussed at some length, but no action was taken by the Club.

The Secretary also read a letter from Mr. E. H. Abadie, chairman of the Local Committee of the American Society of Engineering Contractors, acknowledging receipt of the contribution of the Club toward convention expenses.

The following committees, authorized at the meeting of September 24, were announced:

Meetings and Papers Committee: E. L. Ohle, John Hunter, Mont. Schuyler.

Committee Authorized by the Adoption of the Amended Report of "Advisability of the Engineers' Club withdrawing from the Association of Engineering Societies": J. D. Von Maur, chairman; W. H. Bryan, Andrew O. Cunningham, H. A. Wheeler, A. S. Langsdorf, E. E. Wall, Francis C. Cutts.

The paper of the evening, "The Fourteen-Foot Waterway, St. Louis to Cairo," was then presented by Mr. J. W. Woermann, assistant engineer, Western Division, U. S. A. Mr. Woermann outlined the seven plans which have been considered for creating and maintaining a fourteen-foot channel between St. Louis and Cairo, and gave estimates of each. The paper was illustrated with maps of the river and an atlas showing the nature and location of the various structures proposed.

The paper was of general interest, and created considerable discussion, which was participated in by Messrs. Von Maur, Van Ornum, Moore, Bryan, Flad, Mitchell and Woermann.

The meeting adjourned at 10.15 P.M.

W. W. Horner, *Secretary*.

St. Louis, October 19, 1910. — The 691st meeting of the Engineers' Club of St. Louis was held at a lecture room of the Physics Building at Washington University, Wednesday evening, October 19, at 8.30 o'clock, Vice-President J. D. Von Maur presiding. There were present 22 members and 23 visitors.

The minutes of the 690th meeting were read and approved. The minutes of the 483d meeting of the Executive Committee were read.

Applications for membership of the following were read and referred to the Executive Committee:

Members — Victor H. Becker, Jr.; Pierre C. Grace, George Wm. Lamke, Arthur F. Krippner, George Wightman Wallace, Fred A. Winter.

Associate Member — Lawrence Chappell Kingsland.

Junior — Willard F. Hine.

The following gentlemen were elected to membership:

Non-resident — Robert Lee Kneedler.

Members — Frank Neher, Frederick J. Reinke, Chas. Edw. Smith, Robert M. Strong, Frederick Young.

The Secretary read the obituary of Beriah Warren prepared by Mr. Robert Moore.

Mr. Bryan reported for the Committee on Wider Organization (Mr. Von Maur, chairman) that the committee had met, organized and assigned work to its individual members.

The Secretary announced that Mr. J. D. Robertson had made a donation of books to the club library. It was resolved that the Club extend a vote of thanks to Mr. Robertson.

Mr. Schuyler announced that the Engineers' Club of Milwaukee had requested the Board of Managers of the Association of Engineering Societies

to be allowed to withdraw from the Association. As the request had not been made within the time specified by the rules of the Association, the matter had been put to a vote of the board. Mr. Schuyler requested that the Engineers' Club instruct its representatives on the matter. Mr. Bryan moved that the Club should favor allowing the Milwaukee Society to withdraw immediately as requested. Seconded by Mr. Wall. Motion carried.

Prof. A. S. Langsdorf then gave the paper of the evening on "The Oscillograph," describing the purpose of the machine and giving a description of the earlier machines devised to secure the same results.

He then explained the mechanical operation of the oscillograph, showed several of the curves on a screen and exhibited the photographs of several others.

The meeting adjourned at 10.30 o'clock, after which the members inspected the engineering laboratories of Washington University.

W. W. Horner, *Secretary.*

Boston Society of Civil Engineers.

Boston, October 19, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Henry F. Bryant in the chair. The members of the American Society of Mechanical Engineers and of the Boston Section of the American Institute of Electrical Engineers joined in this meeting, the attendance being about 350.

On motion duly made and seconded, it was voted to dispense with the reading of the record of the September meeting, and to approve the same as printed in the October Bulletin.

The President reported that the following had been elected to membership in the grades named:

Members — Messrs. Charles J. Bonnemort, Walter B. Douglass, Hiram P. Farrow, William F. Hunt and Frank A. Sweet.

Juniors — Messrs. Roy F. Bessey and Herbert P. Bruce.

Associates — Messrs. George M. Clukas and Luke D. Mullen.

The President announced the death of Edwin P. Dawley, a member of the Society, which occurred on October 7, 1910. By vote, the President was requested to appoint a committee to prepare a memoir and he has appointed Past President George B. Francis as that committee.

On motion of Professor Moore, of the Excursion Committee, the thanks of the Society were voted to the Aberthaw Construction Company for the reinforced concrete beam and column furnished for the test which was made this afternoon at the laboratory of the Massachusetts Institute of Technology. The thanks of the Society were also voted to Prof. H. W. Hayward, of the Institute, for his courtesy in conducting the test.

The subject for discussion at this meeting was, "An Account of the Destruction of Cartago, Costa Rica, by the Earthquake of May 4, 1910." Prof. Thomas A. Jaggar, Jr., of the Massachusetts Institute of Technology, was the first speaker, and spoke particularly of the geological features of the earthquake. Prof. Charles M. Spofford followed, discussing the effects of the earthquake on different classes of structures. Both speakers illustrated their descriptions by numerous lantern slides.

Mr. Frank B. Gilbreth, of the American Society of Mechanical Engineers, with the aid of lantern views, gave a very interesting account of the San Francisco earthquake.

A general discussion followed, in which Messrs. Snow, FitzGerald, Caldwell, Larned, and the previous speakers participated.

After passing a vote of thanks to Professor Jaggar, who is not a member of the Society, for his interesting and instructive lecture, the Society adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., October 8, 1910. — The October meeting was called to order at the appointed hour, with ex-President George E. Moulthrop in the chair. The minutes of the September meeting were read and approved. President Bowman of the School of Mines, and delegate to the Conservation Congress held at St. Paul, Minn., September 5–9, gave an exceedingly interesting report of the various sessions of the convention, informing his hearers on several topics to which the press gave but a passing notice.

C. H. Moore, chairman of the Good Roads Committee of the Society, told of the work thus far performed by said committee, and outlined some of its future plans and prospects of success.

The meeting then adjourned.

Clinton H. Moore, *Secretary.*

Utah Society of Engineers.

Salt Lake City, Utah, October 21, 1910. — The regular monthly meeting of the Utah Society of Engineers was held in the Society's headquarters, Newhouse Building, Salt Lake City, on Friday evening, October 21. A paper upon "Manganese Steel" was presented by F. E. Johnson (Edgar Allen American Manganese Steel Company), and the discussion was led by J. R. Tempest (Utah Light and Railway Company). On Saturday, October 29, the Society will visit the new plant of the International Smelting and Refining Company at Tooele, Utah.

W. C. Ebaugh, *Secretary.*

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Association of Engineering Societies.

Vol. XLV. DECEMBER, 1910. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, November 4, 1910. — The 692d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, November 2, 1910, at 8.15 o'clock, Mr. J. W. Woermann, member of the Executive Committee, presiding. There were present 63 members and 27 visitors.

The minutes of the 691st meeting were read and approved. The minutes of the 484th meeting of the Executive Committee were read.

The following gentlemen were elected to membership:

Members — Victor H. Becker, Jr., Pierre C. Grace, Geo. Wm. Lamke, Arthur F. Krippner, Geo. Wightman Wallace, Fred A. Winter.

Associate Member — Lawrence Chappell Kingsland.

Junior — Willard F. Hine.

Applications for membership of the following were read, and referred to the Executive Committee:

Members — Herbert R. Abrams, Albert A. Aergerter, Wm. Bradford, Wm. Gallaher, Donald McArthur, Norman R. McLure, John W. Sykes, Hugo Wurdock.

Associate Member — Louis Stockstrom.

Mr. Bryan reported for the Committee on "Wider Organization."

The following Nominating Committee (provided for by Section II of the By-Laws) was elected: W. G. Brenneke, O. W. Childs, E. C. Dicke, Geo. B. Evans, E. E. Wall.

Mr. Woermann read an obituary of Philip Florreich.

The Secretary read a latter from Mr. W. H. Bryan, president of the Washington University Association, inviting the Club to attend the reception to be held at the University grounds, Saturday, November 5, and announced that a special car for the Club members had been arranged for.

The Secretary read a communication from Mr. J. H. Gundlach, chairman of the Committee of One Hundred, asking the endorsement of the Club of the amendment providing for the establishment of the Public Reservation District. Messrs. Travilla and Pitzman explained object of the amendment and spoke in favor of the proposed Outer Park System. Mr. Travilla moved that the Engineers' Club endorse the scheme for a system of outer parks and

boulevards, as outlined in the Report of the Civic League, and should favor the adoption of the amendment for the reasons given in Mr. Gundlach's letter. Messrs. Greensfelder and Moore also spoke in favor of the motion. Motion seconded and carried.

The Secretary read a letter from Hon. Maxime Reber, president of the Board of Public Improvements, inviting the Club to be the guests of the Board of Public Improvements on a trip, by the harbor boat, to the piers of the Municipal Bridge; and asking the Club to select the time. It was moved by Mr. Zelle, seconded and carried, that the Club accept the invitation of the Board for Saturday, November 12, at 2 P.M., and the Secretary was instructed to notify President Reber.

The following papers were then presented: "The Process of Locating the Municipal Bridge," by Mr. C. M. Talbert, assistant to the president of the Board of Public Improvements; "A Brief Description of the Municipal Bridge," by Mr. E. B. Fay, of Brenneke & Fay, associate engineers on the Municipal Bridge.

Both papers were profusely illustrated by lantern slides, and a large drawing showing the plan and elevation of the bridge was shown.

Mr. Talbert spoke of the difficulties of securing a satisfactory location for the bridge and gave a history of the surveys and legislation which led to the present site and plan.

Mr. Fay described the character of the bridge, and gave a detailed account of the construction of the piers.

A brief discussion followed the reading of the papers, which was participated in by Messrs Pitzman. Moore, Travilla, Childs and Talbert, and was closed by a short address by the Hon. Frederick H. Kreismann, mayor of St. Louis.

At 10.40 the meeting adjourned to the Library Room, where a very attractive lunch was provided by the Entertainment Committee.

W. W. HORNER, *Secretary.*

ST. LOUIS, NOVEMBER 17, 1910. — The 693d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday, November 16, at 8.15 P.M., Vice-President Von Maur presiding. There were present 31 members and 6 visitors.

The minutes of the 692d meeting of the Club were read and approved. The minutes of the 485th meeting of the Executive Committee were read.

The following were elected to membership:

Members — Herbert R. Abrams, Albert A. Aegerter, Wm. Bradford, Wm. Gallaher, Donald McArthur, Norman R. McLure, John W. Sykes, Hugo Wurdock.

Associate Member — Louis Stockstrom.

Applications for membership from the following were read:

Members — A. S. Miller, Chas. M. Hummel, Hugh E. Hale, Wm. G. Todd.

Associate Member — John S. Bronson.

Junior — Fred L. Block.

The Secretary read a letter from the National Rivers and Harbors Congress concerning the meeting in Washington in December. It was moved, seconded and carried that the letter be referred to the President with power to act.

Mr. Pfeifer moved that all arrangements for the annual banquet be referred to the Entertainment Committee. Motion seconded and carried.

Mr. Woermann moved that a limiting price of $2.50 a plate for the annual dinner be set. Motion lost.

Mr. Pfeifer moved that the matter of price per plate be referred to the Entertainment Committee. Seconded and carried.

Mr. Greensfelder offered the following resolution which was unanimously adopted:

"The Engineers' Club of St. Louis wishes to express their thanks for the courtesy extended by the Honorable Mayor and Board of Public Improvements in affording them the opportunity of visiting the site of the Municipal Bridge and observing the sinking of the caisson and the construction of the piers. The Club, appreciating the many difficulties, structural and otherwise, attendant upon this work, feels that the municipality should be congratulated upon the efficient manner and progress in which this undertaking has been forwarded."

The Nominating Committee presented the following report:

To the President and Members of the Engineers' Club of St. Louis:

Gentlemen, — The Nominating Committee begs to submit the following members as candidates for the various offices of the Club for the ensuing year:

President, J. D. Von Maur; Vice-President, A. S. Langsdorf; Secretary and Librarian, W. W. Horner; Treasurer, Wm. E. Rolfe; Directors, Wm. C. Zelle, Oliver W. Childs; Board of Managers, John Hunter, Ernest L. Ohle, Wm. S. Henry.

Respectfully submitted,

(Signed) O. W. Childs.
E. E. Wall.
E. C. Dicke.
George B. Evans.
W. G. Brenneke, *Chairman.*

Mr. Schuyler presented the paper of the evening, entitled, "Certain Theoretical Aspects of Specifications."

Adjourned 10 P.M.

W. W. Horner, *Secretary.*

Boston Society of Civil Engineers.

Boston, November 16, 1910. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President Henry F. Bryant in the chair; 105 members and visitors present.

It was voted to dispense with the reading of the record of the October meeting and to approve the same as printed in the November *Bulletin.*

The President reported that the following had been elected members of the Society: Messrs. Ernest W. Day, Harold C. DeLong, Henry L. Hardy, Louis K. Rourke and James H. Sullivan.

Mr. Howe, for the Board of Government, announced that Past President Desmond FitzGerald had very generously offered to provide a medal as a prize for the best paper read before the Society. The question of the advisa-

bility of offering such a prize was referred to the board at the last annual meeting of the Society, and the board now desired authority to report in print in the next issue of the *Bulletin.* The authority was accordingly granted.

Professor Moore, for the Committee on Excursions, offered the following votes and they were unanimously adopted:

" That a vote of thanks be extended to Mr. Geo. H. Snell, superintendent of the Attleboro Water Works, for courtesies extended this afternoon on the occasion of a visit of members of the Society to the work now under construction on the new dam."

" That a vote of thanks be extended to the C. F. Trumbull Company for courtesies extended to members of the Society on the occasion of a visit to the filter beds recently completed by that company in North Attleboro, Mass."

The paper of the evening was by Mr. Charles R. Gow, and was entitled, " Methods and Costs of Construction of Slow Sand Purification Plant for the new Springfield, Mass., Water Works."

As the paper had been printed in full with illustrations, and sent with the notice of the meeting, Mr. Gow presented, in abstract, only the more interesting portions of the paper, which he illustrated by the aid of lantern slides.

The Secretary read a discussion of the paper prepared by Mr. Allen Hazen, who was unable to be present; and Messrs. E. E. Lochridge, W. S. Johnson, S. E. Thompson, C. R. Gow and others participated in the discussion.

Adjourned.

S. E. TINKHAM, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., NOVEMBER 14, 1910. — The seventh regular meeting of the year was called to order in the Society's quarters in the Old State Capitol Building at 8.30 o'clock P.M. by President J. D. DuShane. There were present seven members, one junior and two visitors.

The minutes of the previous meeting were read and approved.

Mr. DuShane stated that his name had been selected by Mayor Keller of St. Paul as a representative of this society to serve on the committee of one hundred citizens to consider comprehensive plans for the future development of the park system of the city. The Society expressed its desire that Mr. DuShane should serve on said committee in its behalf, and should advise the mayor of his acceptance.

The request of Secretary Brooks of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for matter for publication in the JOURNAL was brought to the attention of the Society. Upon motion duly seconded it was carried that the Secretary send a written request for such matter to the members, and urge reasonable haste in the preparation of such papers.

A discussion on general engineering matters was then participated in, and the meeting adjourned.

D. F. JÜRGENSEN, *Secretary.*

Montana Society of Engineers.

Butte, Mont., November 12, 1910. — The meeting of the Society for October was held on the above date, with President Frank M. Smith in the chair. The minutes of former meeting were approved. The application of George Arthur Packard for membership was read, approved and the regular ballot ordered. The report of the Committee on Nominations for officers for the coming year was read as follows:

For President — F. W. C. Whyte.

First Vice-President — Robert A. McArthur.

Second Vice-President — John H. Klepinger.

Secretary and Librarian — Clinton H. Moore.

Treasurer and Member of the Board of Managers of the Association of Engineering Societies — Samuel Barker, Jr.

Trustee — Willis T. Burns.

Helena, Mont., was chosen as the place for the next annual meeting.

Adjournment.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

Meeting of its officers and past officers at the residence of the Secretary, 1926 Broadway, San Francisco, at 8 o'clock p.m., on Wednesday, November 30.

President George W. Dickie called the meeting to order.

A general discussion took place, in which all those present participated, the result of which was that the Society should be continued and that an effort should be made to consummate a certain coöperation with the other engineering societies for the purpose of making these organizations more popular with, and of greater utility to, the public.

It was concluded to hold the annual meeting about the middle of January, 1911, that a banquet be given on that evening and that the election of officers take place then.

The following Nominating Committee was appointed: Marsden Manson, chairman; C. E. Grunsky, Harry Larkin, Adolf Lietz, Richard Keatinge.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

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